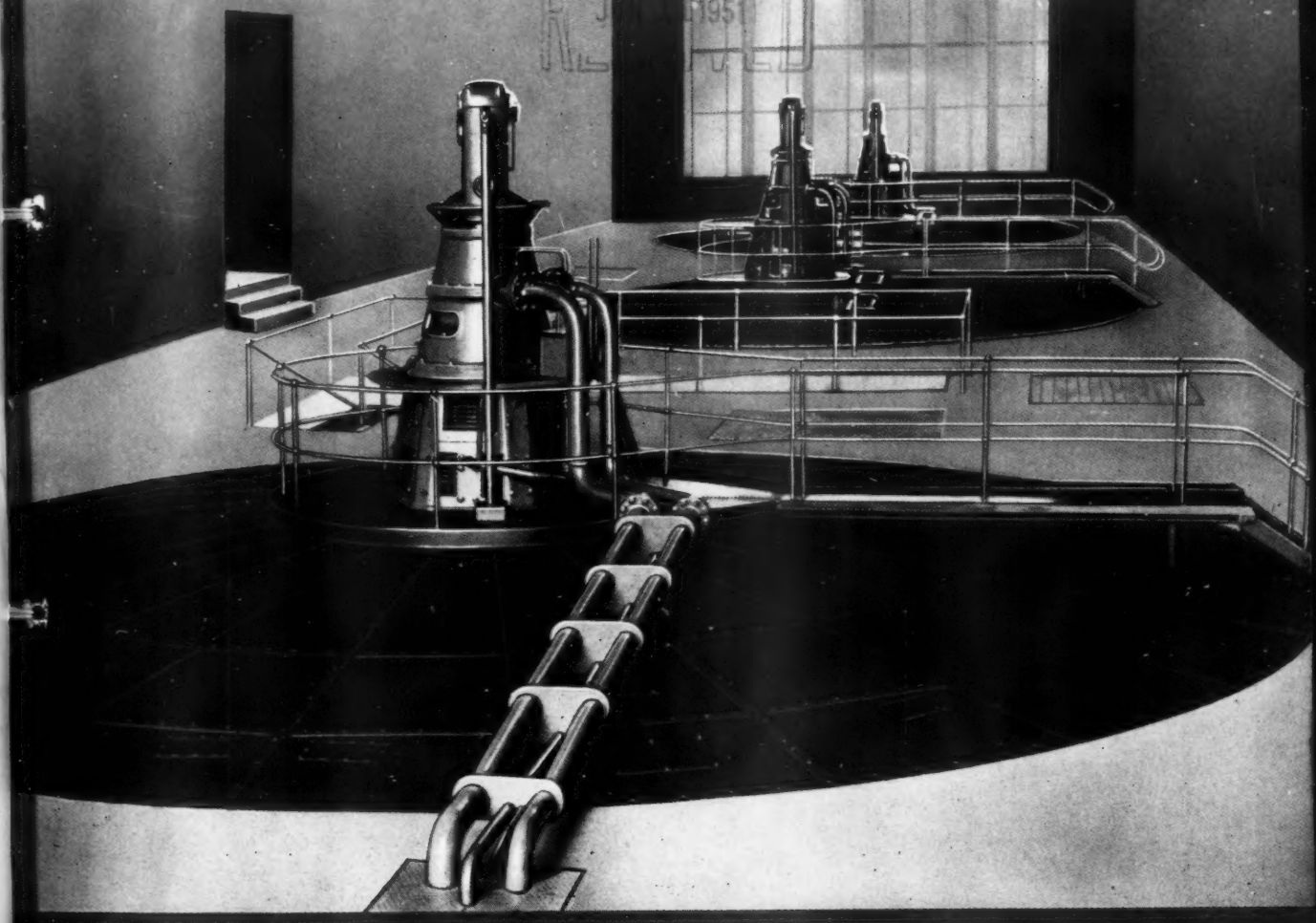
TJ627.W3

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

APRIL 1951

JAN 1951



MORE POWER

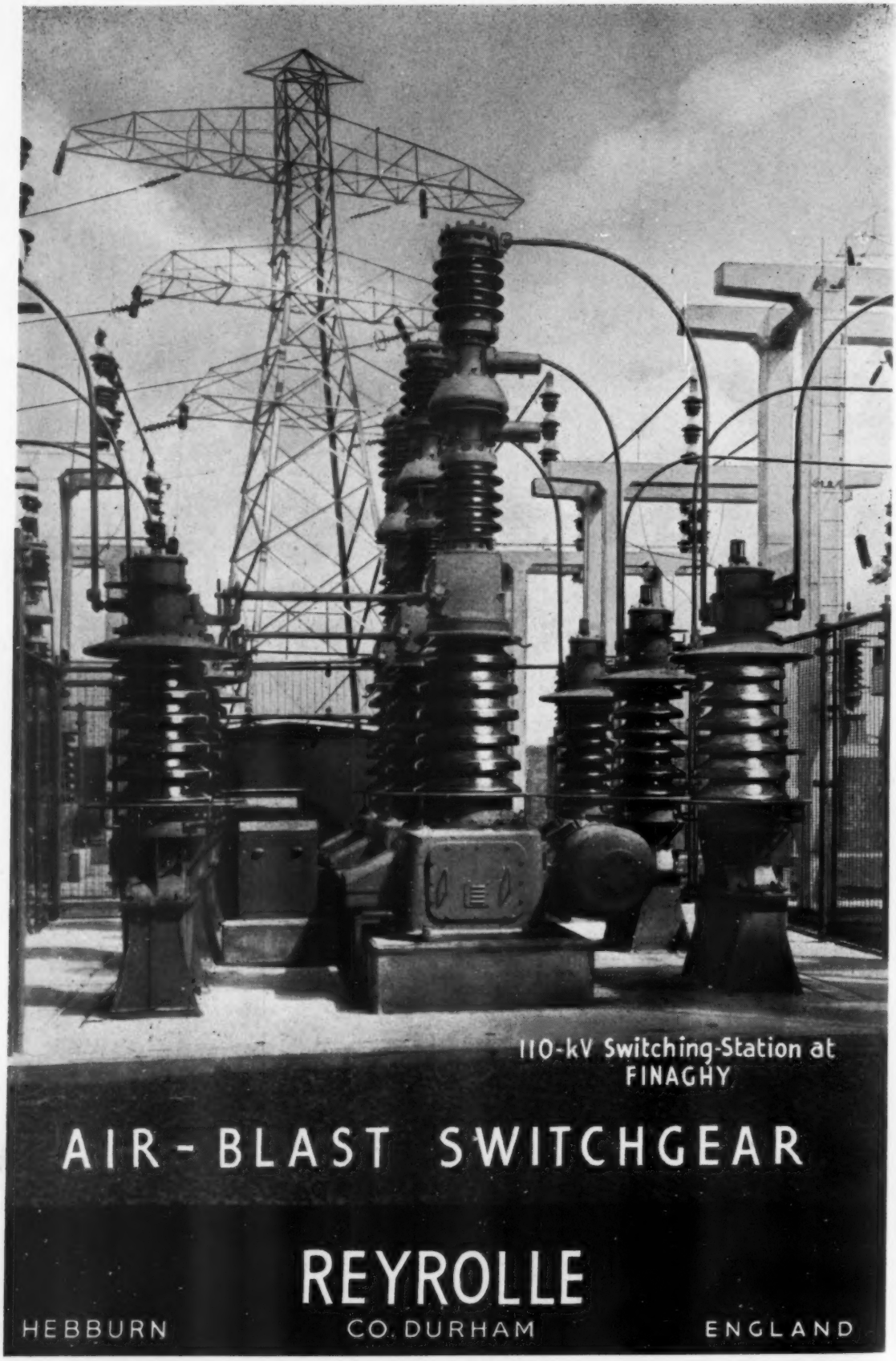
These three 18,000 KVA 75 r.p.m. generators with stators of 36' diameter, shown operating in the Taniankoski hydro-electric station of Enzo-Gutzeit, are the largest in Finland. Other M-V hydro-electric equipment contributing towards Finland's industrial development includes power transformers and air-blast switchgear.

Today the prosperity of any country is directly dependent on the amount of electric power available. The Metropolitan-Vickers organisation, by supplying equipment for the generation, transmission, distribution and application of electrical energy in all parts of the globe, is making an important contribution to world prosperity.

GENERATORS · TRANSFORMERS
SWITCHGEAR · SYNCHRONOUS
CONDENSERS · AUTOMATIC
CONTROL EQUIPMENT ·
VOLTAGE REGULATORS etc.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., MANCHESTER 17, ENGLAND

Member of the A.E.I. group of companies


110-kV Switching-Station at
FINAGHY
AIR-BLAST SWITCHGEAR
REYROLLE
HEBBURN
CO. DURHAM
ENGLAND

KUUSANKOSKI
FINLAND
KAPLAN RUNNER
51,200 B.H.P.
CLUNIE
SCOTLAND
FRANCIS RUNNER
28,700 B.H.P.
Two typical large runners for Boving Turbines photographed on completion of manufacture at the works of John Brown & Co., Ltd., Clydebank. The Kaplan runner blades are of solid cast stainless steel.
Boving
& COMPANY LIMITED
WATER POWER ENGINEERS

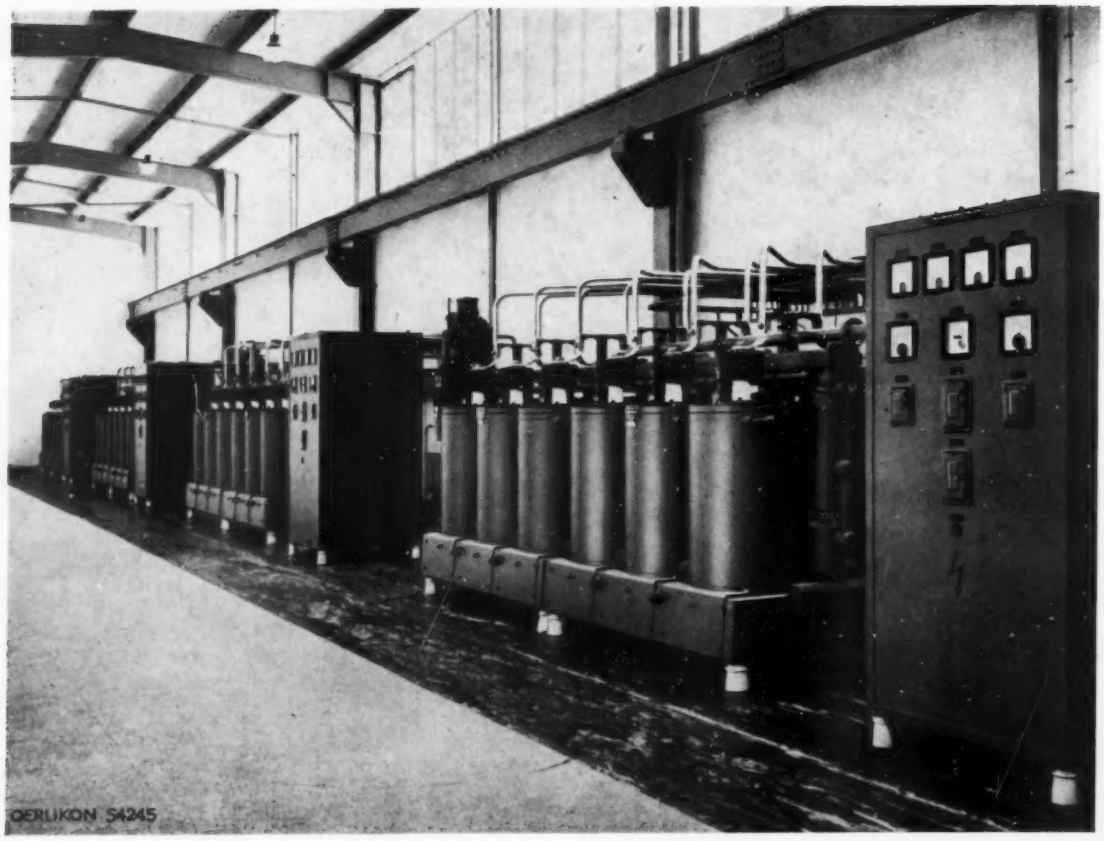
B.C.12

Head Office: 56, KINGSWAY, LONDON, W.C.2, ENGLAND

Wellington: Druids Chambers, Woodward Street.
Melbourne: 99, Queen Street.
Calcutta: Macneill & Barry Ltd., 2, Fairlie Place.
c/o Messrs.
Chittagong (Pakistan): c/o Messrs. Macneill & Barry Ltd., Strand Road.

OERLIKON

Electrical machinery and apparatus



Four Oerlikon single anode rectifier units each for 4500 kW, 6000 A, 750 V, in an electrochemical plant.

OERLIKON PRODUCTS:

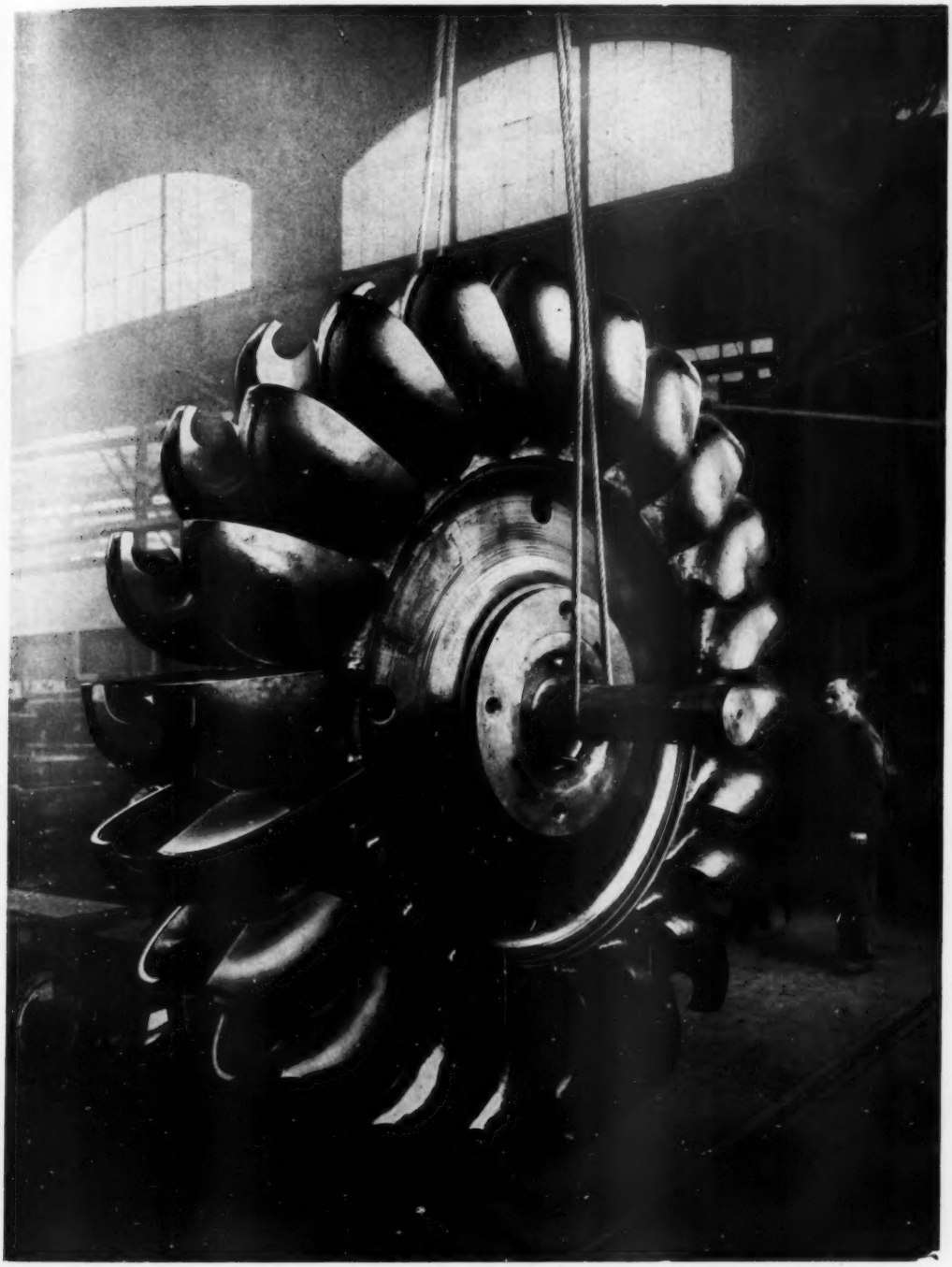
Complete electrical equipments for hydro-electric and steam power stations, sub-stations and distribution installations.

Generators, Motors, Transformers, Mercury Rectifiers, Induction Regulators ; Motor Generator Sets. **Electrical Apparatus** for High and Low Voltage (Oil Circuit-Breakers, Minimum Oil Circuit-Breakers, Air-Blast Circuit-Breakers, Isolating Switches, Step-Switches, Protective Switch-boxes, etc.) Voltage Regulators ; Relays, Lightning Arresters. Switch and Distribution Stations. Arc Welding Plants.—**Electrolysers** for the production of Hydrogen and Oxygen.

Steam and Gas Turbines. Turbo-Alternators.

Electrical Equipments for Locomotives, Motor Coaches, High-Speed Railcars, Diesel Electric Vehicles, etc. (for Standard and Narrow Gauge Railways, for Mountain and Rack Railways, etc.), Tramways, Trolleybuses, Ropeways, Cable Railways, Snow ploughs. —Compressors and Vacuum Pumps for Vehicles.—Rectifier Plants.

ATELIERS DE CONSTRUCTION OERLIKON, ZURICH 50 (SWITZERLAND)



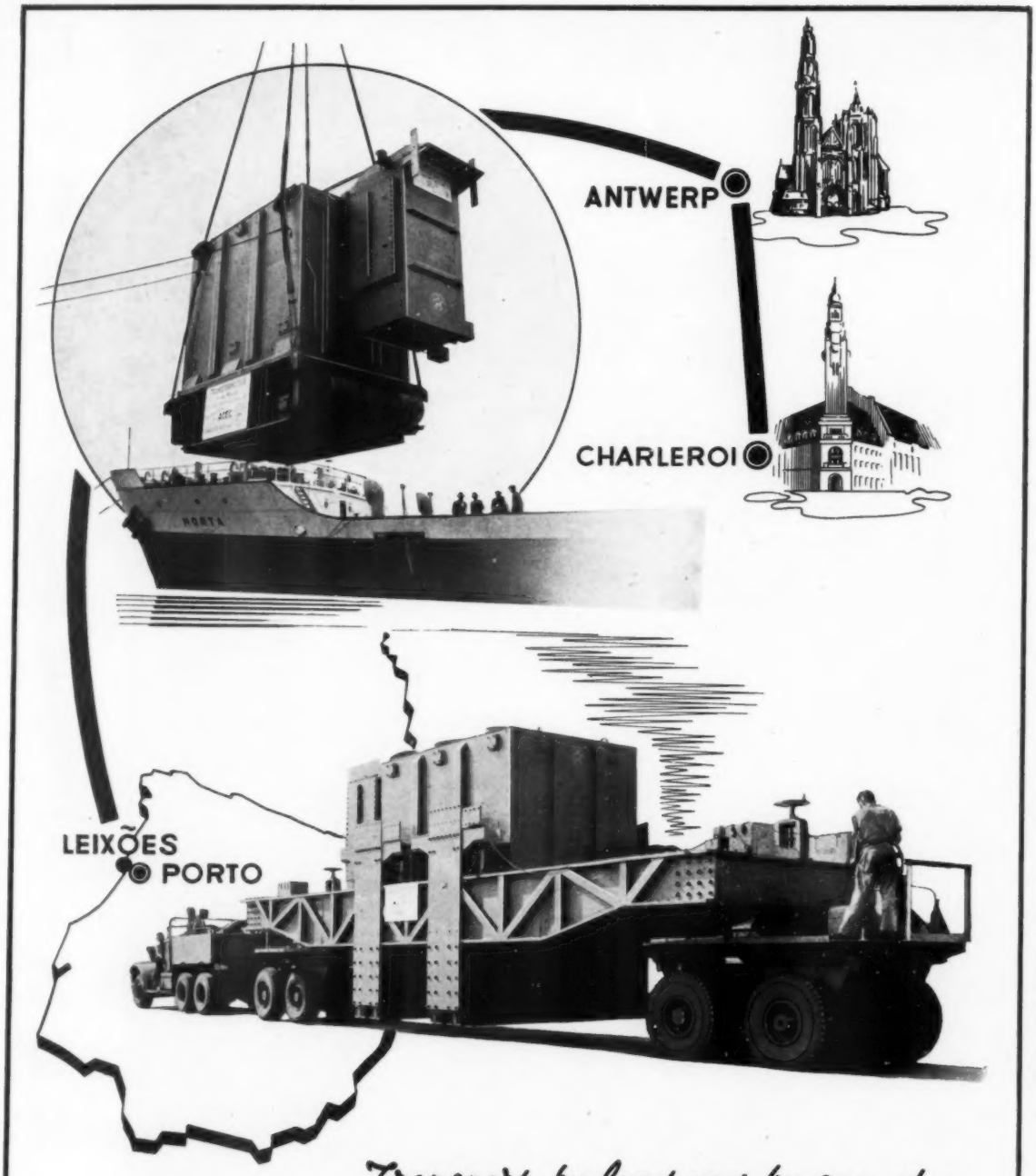
Impulse type runner cast in one piece and developing about 66,000 h.p. Supplied to the Kraftwerke Oberhasli A.G. for their Innertkirchen Power Station. The total output of the turbines ordered from Escher Wyss by these clients for the Innertkirchen, Handeck and Grimsel power plants exceeds 500,000 h.p.

We further specialize in Kaplan and Francis turbines up to the largest outputs and heads, as also in large storage pumps and other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)

ESCHER WYSS ZURICH



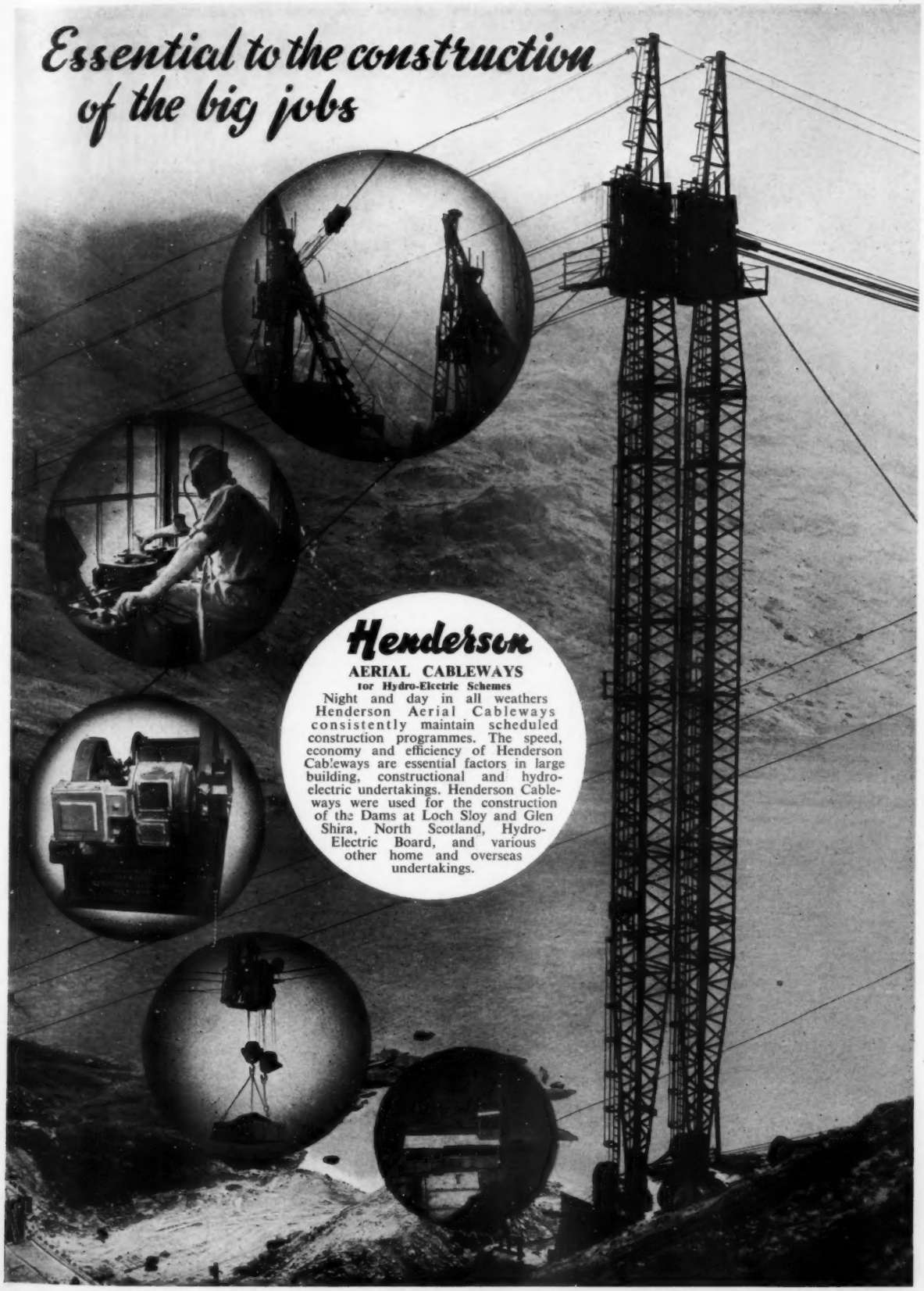
Transport by land and by sea of a
45.000 kVA · 150.000 V · 63.000 . 10.000 V.
"SHELL" TYPE THREE-PHASE TRANSFORMER

On-load tap changer on the H.V. *winding*
Overall weight, oil included : 137 T
Shipping weight : 82 T

CHARLEROI CAEC

Ateliers de Constructions Electriques de Charleroi

Essential to the construction of the big jobs



Henderson

AERIAL CABLEWAYS

for Hydro-Electric Schemes

Night and day in all weathers Henderson Aerial Cableways consistently maintain scheduled construction programmes. The speed, economy and efficiency of Henderson Cableways are essential factors in large building, constructional and hydro-electric undertakings. Henderson Cableways were used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

JOHN M. HENDERSON AND COMPANY LIMITED · KING'S WORKS . ABERDEEN Phone 24262

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Are your generators reliably protected?

Will they be de-energised immediately a fault occurs in the windings?

Brown Boveri generator protecting equipment

reliably detects the different types of faults and will effectively safeguard your machines

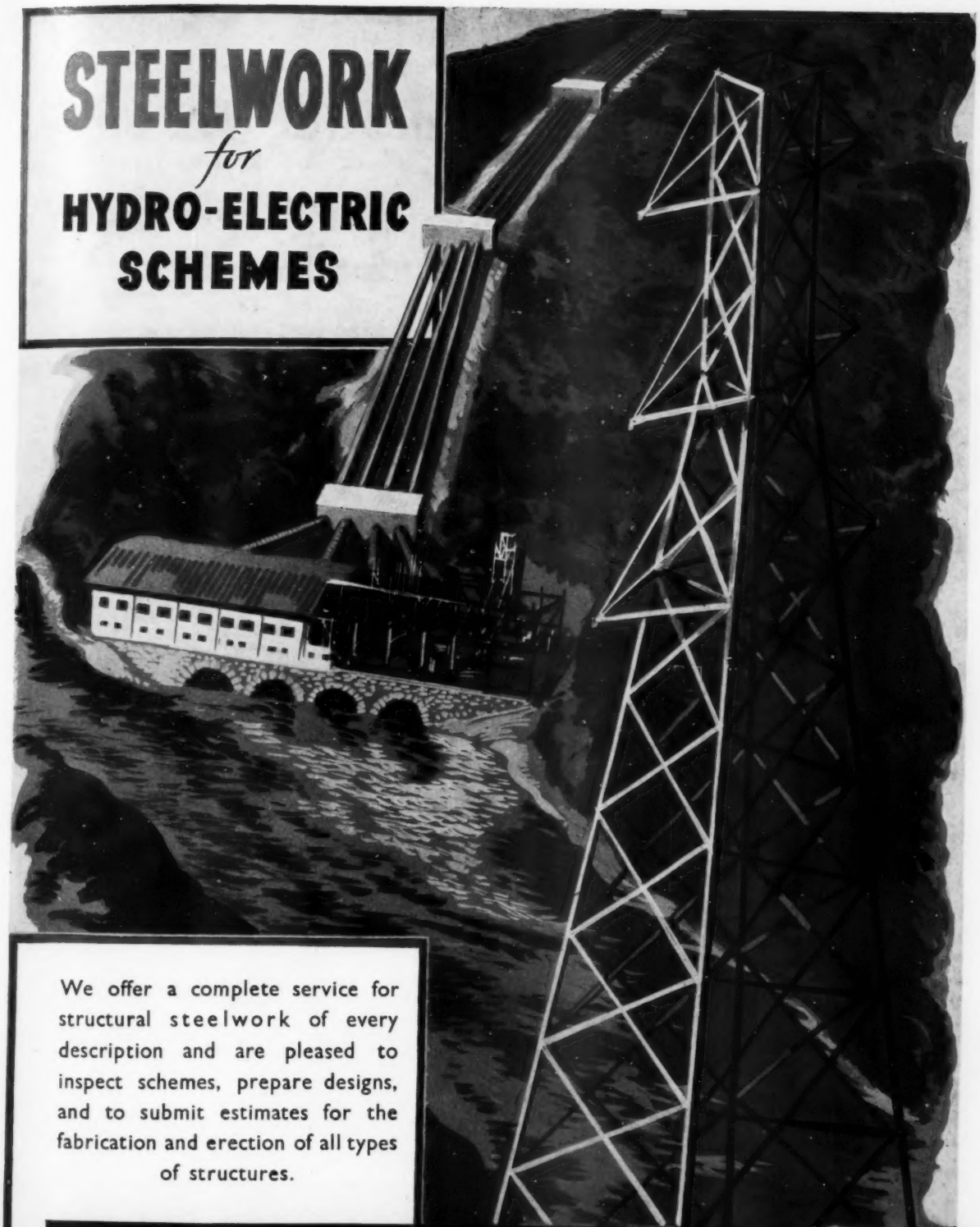
Hundreds of power stations are equipped with our protective gear

Let our specialists advise you

View of machine hall of a Swiss power station, showing two of the three Brown Boveri alternators rated 19500 kVA, 75 r.p.m., 50 c/s.

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

STEELWORK *for* HYDRO-ELECTRIC SCHEMES



We offer a complete service for structural steelwork of every description and are pleased to inspect schemes, prepare designs, and to submit estimates for the fabrication and erection of all types of structures.

ROBINSON and KERSHAW LTD

TEMPLE STEELWORKS · GLOBE LANE · DUNKINFIELD · CHESHIRE

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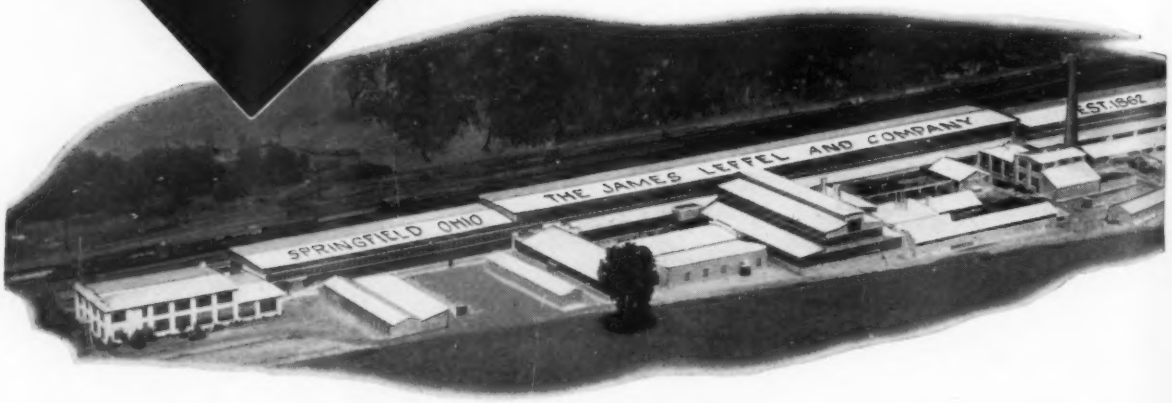
leffel

Hydraulic Turbines

. . . a mark of quality for 89 years



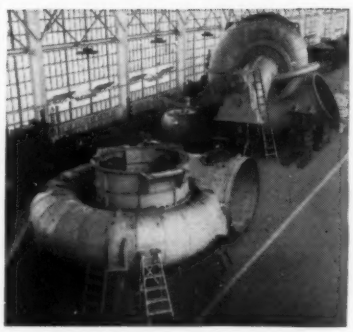
During the course of 89 years many reputations are made and destroyed, many companies rise and fall. Only by the sheer weight of integrity in every phase of its performance of duty can a company win and hold the approval of those with whom it does business.

If, through such a period of time, there is no moment of weakness in the determination to maintain the finest standards of engineering and production, the company will be, today, in the best position in all its history to serve its customers.

It takes time to judge an hydraulic turbine. Quality, or the lack of it, may not be fully apparent for a brief time—yet day after day, year after year, the turbine rewards or penalizes the buyer. **Price or promise may sell, but only integrity can deliver.** As time goes on, the conscientious turbine builder finds himself with widening opportunities to serve.

Not once during 89 years has Leffel yielded to the temptation to lessen its prestige for the sake of a cheaper product to meet competition. And so, because the service that a company renders over the years is a basic ingredient in its reputation, especially in a long-time investment such as that in an hydraulic turbine, hydraulic turbine buyers entrust their water-power problems to Leffel **with complete confidence.**

In the future, as in the past, if you want the finest in hydraulic turbine construction and performance your choice of Leffel will be inevitable.



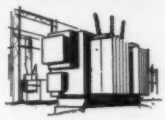
Leffel vertical and horizontal shaft hydraulic turbines on our assembly floor.

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 89 YEARS



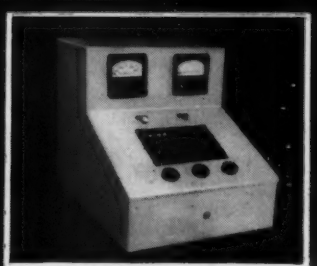
Man with a Hundred Hands

A MAN'S HANDS can be multiplied by a hundred . . . or even a thousand . . . at a Westinghouse Supervisory Control panel. This unique electrical mastermind gives him *complete selective control and automatic indication at all times for an entire power supply system,* including associated transmission lines, substations and circuit breakers. It assures uninterrupted power service . . . for higher operating efficiency—and saves time and manpower . . . for lower operating costs.

Westinghouse, originator of the first successful method of centralized power control, offers 5 different types of Supervisory Control Systems for a wide range of power and industrial applications. These Systems are capable of positive control over longer distances than any other equipment on the market and are ideal for remote direction of hydroelectric power stations, electrified railways substations, and electrified pipe-line pumping stations.

No matter how big or how small your power system, Westinghouse Supervisory Control gives you precise and positive control of every unit . . . or of specific sections. Send us a layout of your system and specify the functions to be performed—we'll be glad to draw up detailed recommendations for a Westinghouse Supervisory Control installation.

TO FIND OUT HOW Westinghouse Supervisory Control can raise the operating efficiency and lower the operating costs of your power system, write for your free reprint of "By a Flick of the Finger," an informative 5-page article on the subject.



***Visicode, Jr.,** low-cost version of the larger Visicode system, especially designed for economical operation of small stations.*

WESTINGHOUSE SWITCHGEAR

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WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

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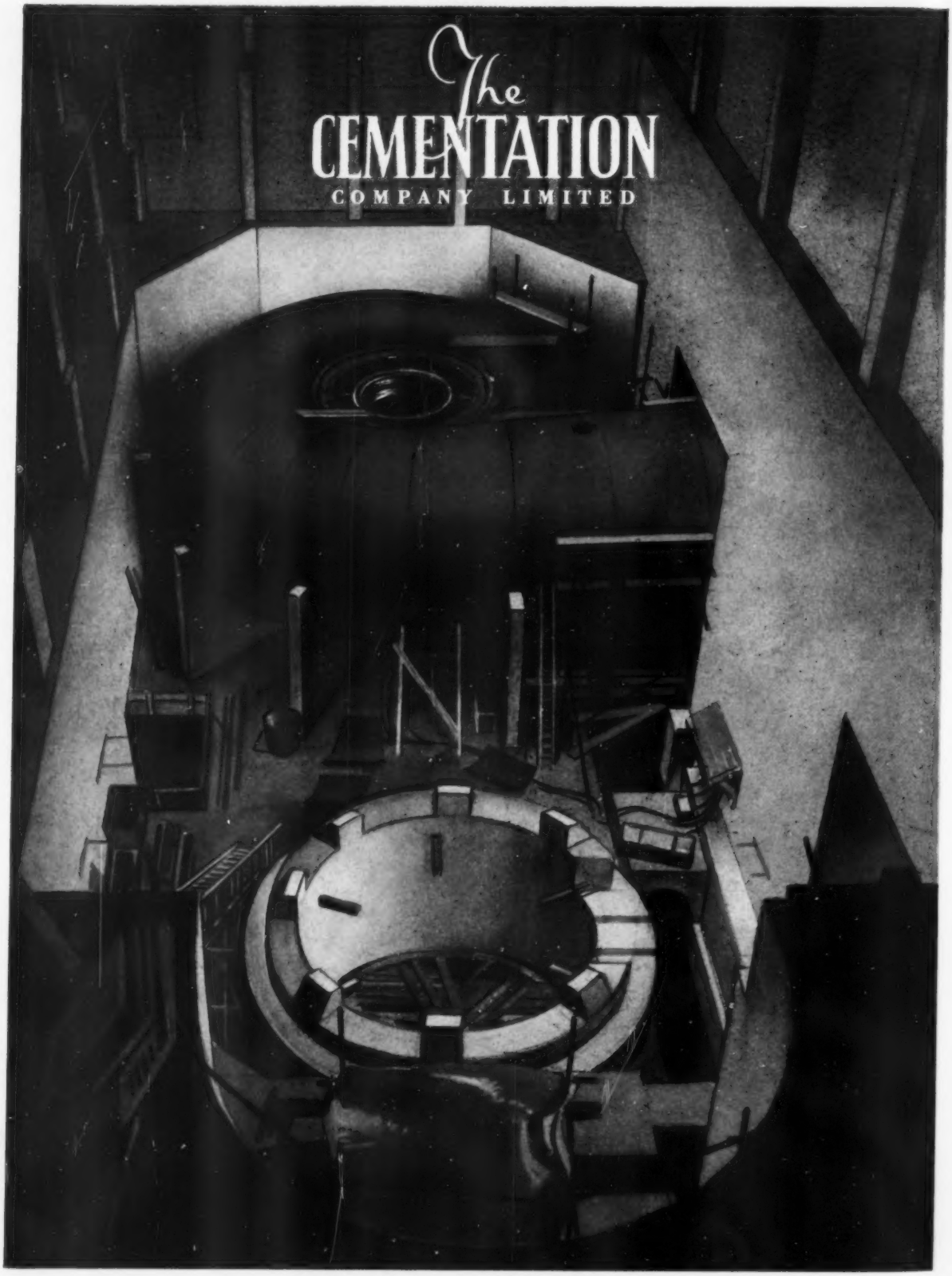
The Cementation Co. Ltd. are the Civil Engineering Contractors to the Electricity Supply Board of Eire for the 75,000 kVA Erne Hydro-Electric Development

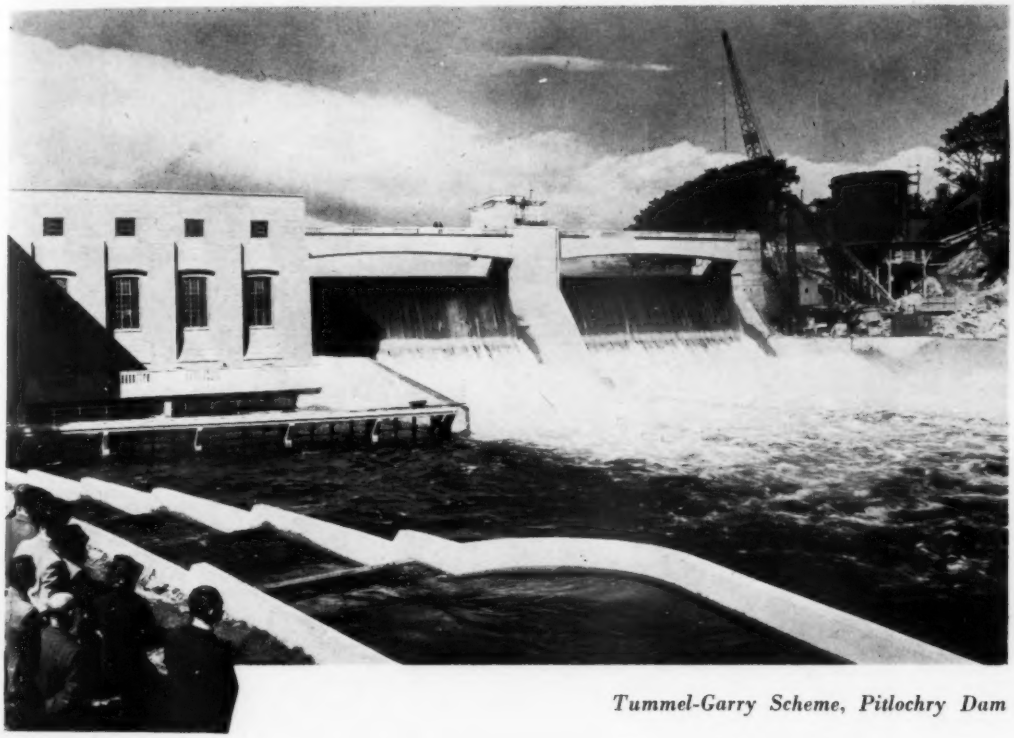


Cathleen Falls Power Station under construction

BENTLEY WORKS — DONCASTER

PHONE: DONCASTER 54177-8-9 — LONDON OFFICE: 39 VICTORIA STREET, S.W.1 — PHONE: ABBEY 5726-7-8

SHOP WINDOW FOR BRITISH ENGINEERING



Tummel-Garry Scheme, Pitlochry Dam

The North of Scotland Hydro-Electric Board are harnessing the water power resources of the Highlands of Scotland, which are estimated to have a potential annual output of 10,000,000,000 kilowatt hours, distributing electricity in an area of 21,750 square miles and also supplying power to Britain's National Grid.

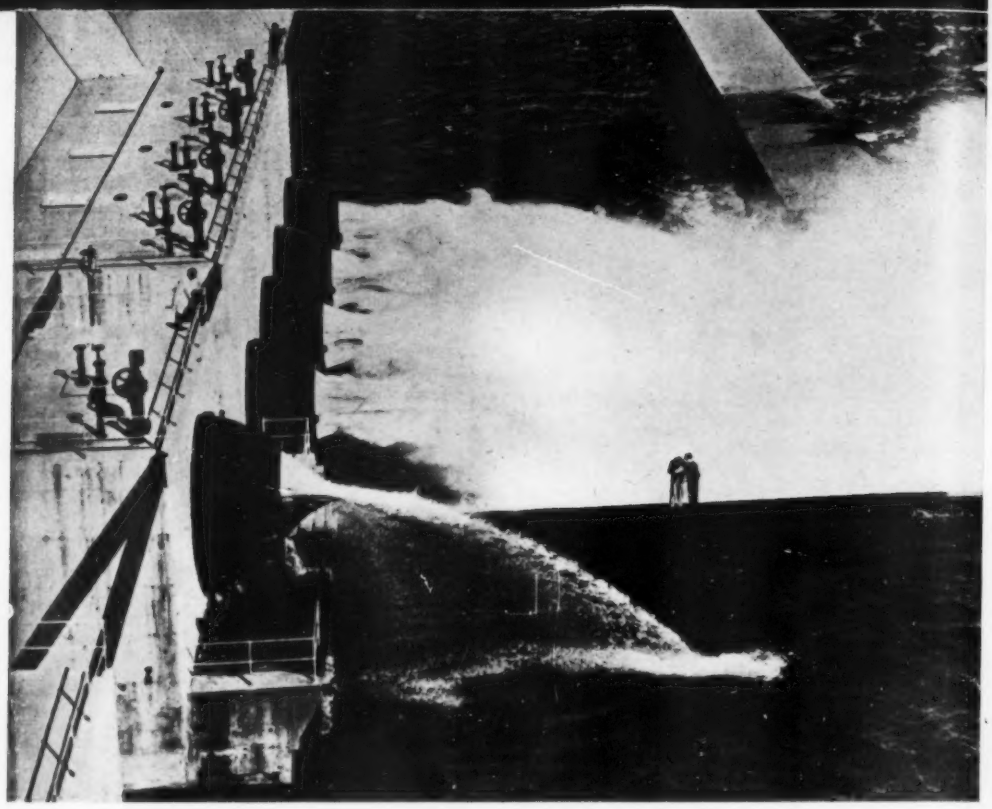
More than one hundred hydro-electric schemes are visualised in this development.

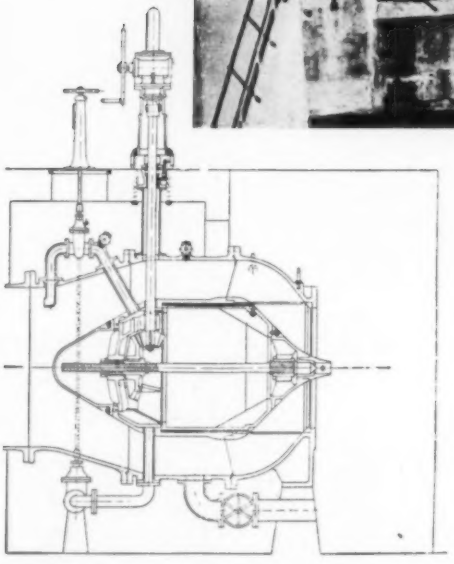
Schemes with an estimated annual output of 3,300,000,000 kilowatt hours and a kilowatt capacity of 1,126,000 are in operation, under construction or in preparation.

On the doorstep of world-famous engineering firms the visitor will see a wide range of generating machinery and equipment operating under diverse conditions.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD

DISCHARGE REGULATORS FOR DAM OUTLETS



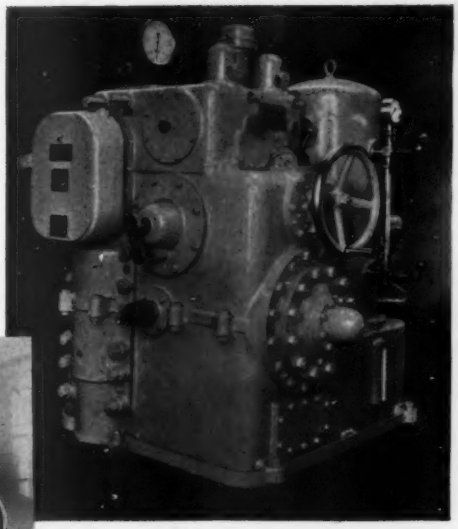


The Larner-Johnson valve possesses exceptional qualities for free discharge control. No other valve provides so complete an answer to the dual problems of high velocity flow and hydraulic unbalance associated with this duty. Being of true streamline form, it passes a smooth jet at all openings, giving freedom from vibration and erosion under the highest heads. Operation is by means of the pipe line pressure acting on the plunger, governed by an internal pilot valve control which holds the plunger in balance at all open positions (when stationary) and creates the appropriate unbalance for opening or closing. Ease of operation is thus ensured, irrespective of size or pressure. Simplicity of design, freedom from distortion troubles, absence of sliding surfaces under pressure, all contribute to the success of the valve over the full range of conditions. Some of the largest valves of their class are of Larner-Johnson type, amongst them the three 13 ft. by 7 ft. 6 in. and four 9 ft. by 7 ft. 6 in. regulators at Hume Dam, on the Murray River, Australia, certain of which appear in the adjoining photographic view.

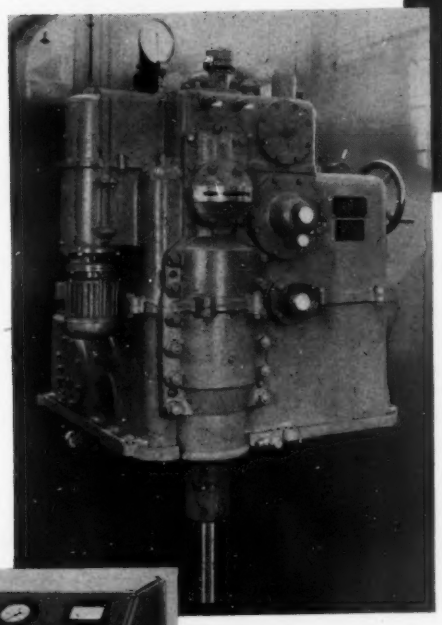
Full particulars from : J. Blakeborough & Sons Ltd., Brighouse, England.

BLAKEBOROUGH

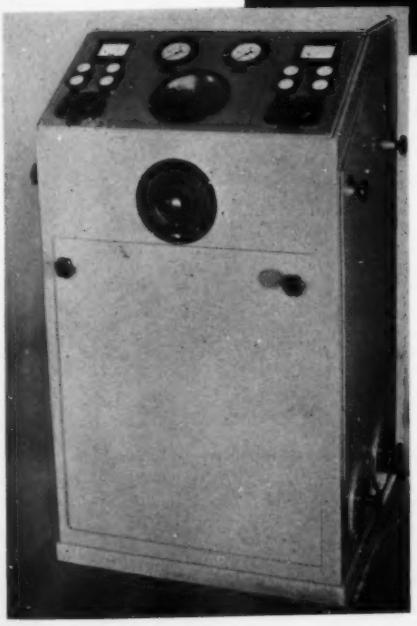
NOHAB



1310 *Governor arranged for propeller type turbine with blade regulation.*



1421 *Governor arranged for Francis type turbine*



10023 *Control desk for electro-hydraulic regulation.*

NOHAB WATER TURBINES

are equipped with modern

OIL PRESSURE GOVERNORS

Our new series of governors is designed for Francis and propeller type turbines and can be arranged for full or half automatic service and for distance operation.

Servomotor, oil pump, pressure oil tank and actuator are combined in one unit.

The illustrations show two types of governors for different designs of turbines. (Photos 1310 and 1421).

We also manufacture electrically operated turbine governors in co-operation with the well-known ASEA Company. (Photo 10023).

NYDQVIST & HOLM AKTIEBOLAG, Trollhättan, Sweden

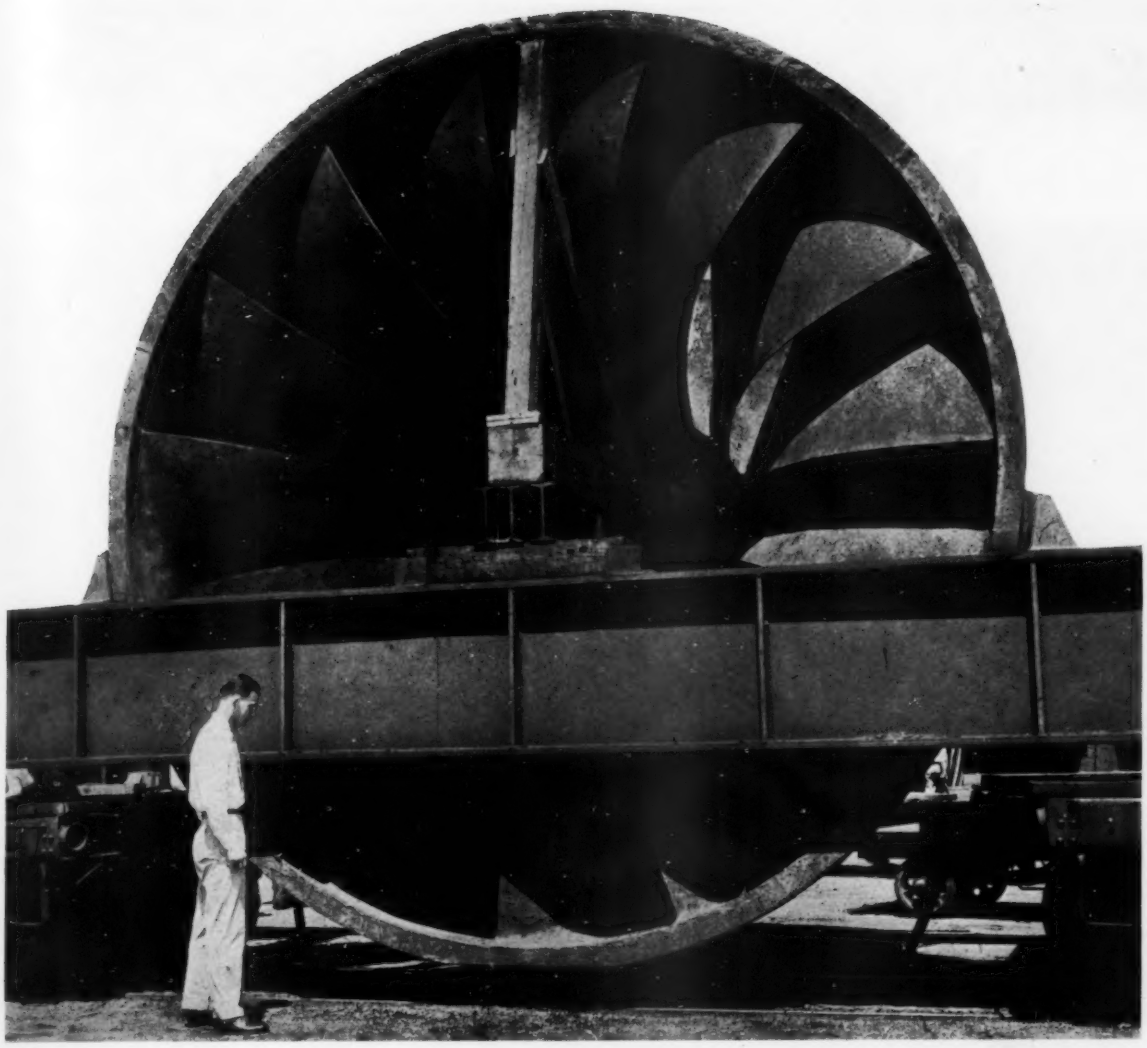
Telegrams: Nohab, Trollhattan Codes: ABC 6th ed., Bentley's

HYDRO - ELECTRIC PLANT

by G.E.C.

for
ASIA
AFRICA
CANADA
AUSTRALIA
SOUTH AMERICA
ETC.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



FACILITIES FOR THE SMALLEST OR LARGEST

The 225-acre Newport News plant includes plate steel and machine shops equipped with a complete variety of tools to fabricate items of water power equipment of any size. Contracts received by Newport News for hydraulic turbines with an aggregate rated output in excess of 7,000,000 horsepower have included units as high as 165,000 horsepower and as low as 500 horsepower.

Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

NEWPORT NEWS

SHIPBUILDING AND DRY DOCK CO.

NEWPORT NEWS, VIRGINIA, U.S.A.

Keeping the Sea at Bay with MILLARS' WELLPOINTS

BIF 1951

APRIL 30—MAY 11
CASTLE BROMWICH
BIRMINGHAM

SEE OUR EXHIBIT

STANDS 1211, 1110

This amazing example of the efficiency of Millars' Wellpoint Dewatering System is actually in the sand on the seashore, within a few feet of the breakers. The excavation is 14 ft. deep below sea level and is entirely without supporting timber. The whole of this contract, which consisted of construction of a large outfall culvert in waterlogged sand, was carried out by the use of Millars' Wellpoints.

Write for further details to Dept. W.P.5.

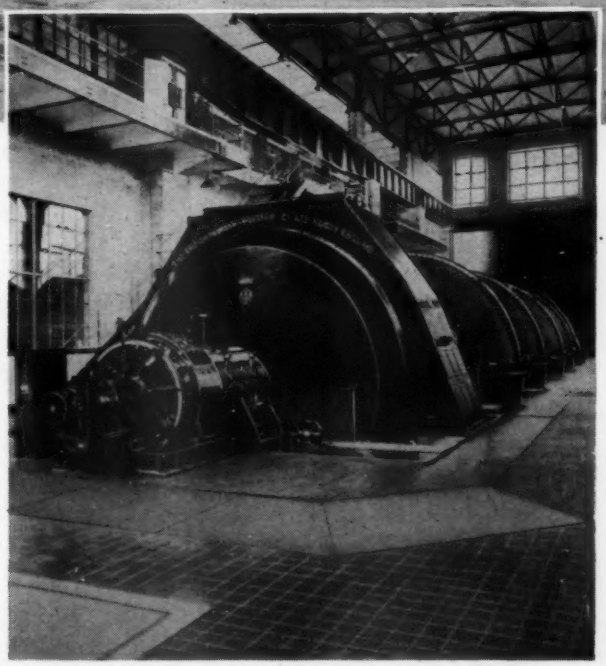
MILLARS' MACHINERY COMPANY LIMITED

Head Office : THORLEY WORKS · BISHOP'S STORTFORD · HERTS. Telephone : Bishop's Stortford 694/5

Wellpoint Dept. : CROMFORD HOUSE · CROMFORD COURT · MANCHESTER 4. Telephone : Blackfriars 8813/4

33.636

Hydro-electric Equipment



General view of Tummel Power Station —Messrs. The Grampian Electricity Supply Co. Ltd.

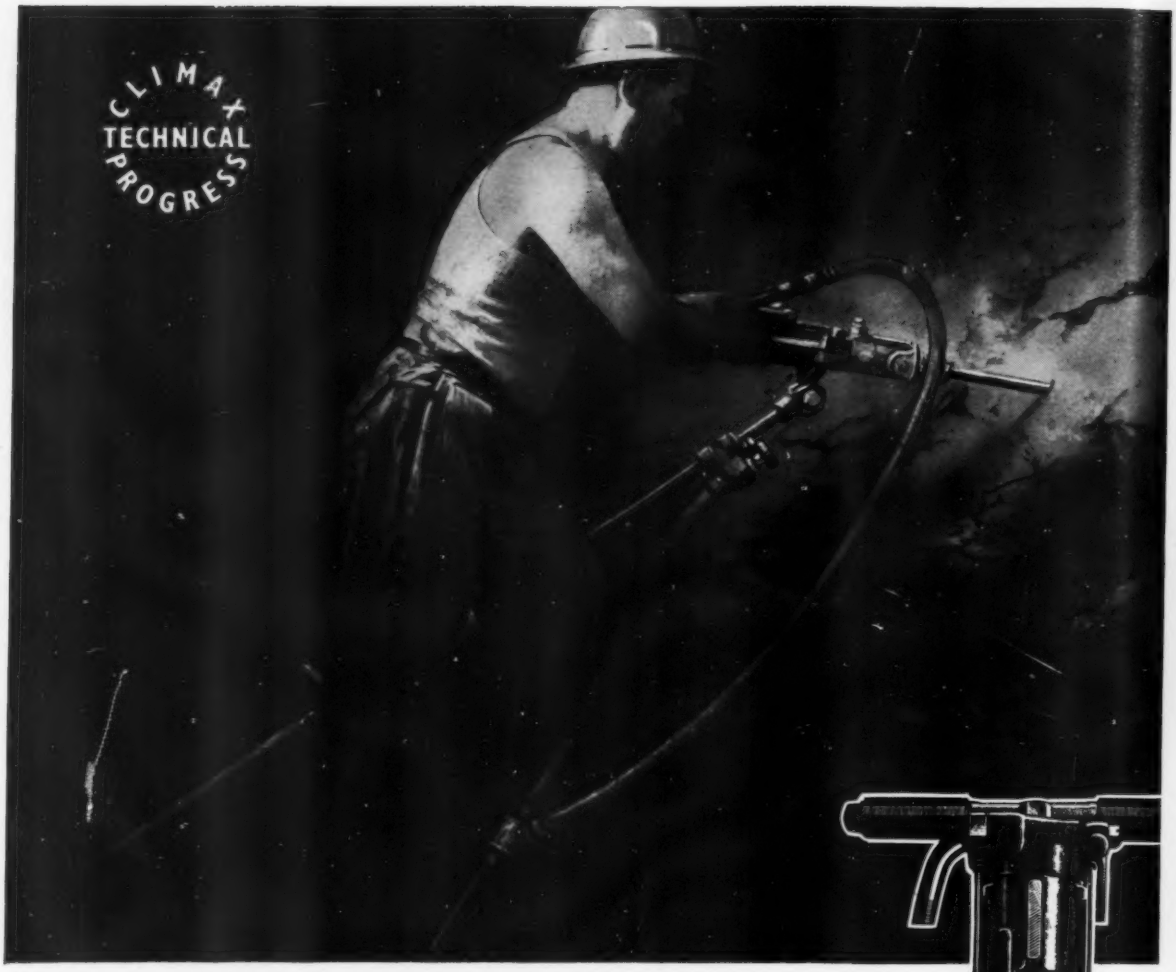
21,250 kVA, 300 r.p.m. 11,000/13,000 volt, 50 cycle, three-phase waterwheel-driven alternators (horizontal type) installed in the Tummel Power Station.

For all plant required for Hydro-electric Power Schemes— Consult B T H

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO. LTD. RUGBY, ENGLAND

AJ879



GREATEST FOOTAGE—LEAST FATIGUE

The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

CLIMAX

CLIMAX ROCK DRILL & ENGINEERING WORKS LTD.

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TAS/CX 480

LOGAN for Tunnelling Transport

NO FUMES, NO NOISE
NO GEAR CHANGE
NO FUEL PROBLEMS
LARGE OVERLOAD CAPACITY
ALL WORKING PARTS READILY ACCESSIBLE

EASY TO HANDLE
LOW MAINTENANCE COSTS
EASY START AND STOP

Trolley Locomotives in sizes from 5 to 15 tons, Gauge 19in. to 42in. with Trolley, Slipper or Pantagraph Collector.

Battery types in sizes from 2 to 12 tons. Gauge 18in. to 42in. Battery container easily removable.

The illustrations show combined Trolley Battery Locomotives supplied to the Vest Agder Hydro-Electric Scheme in Norway

THE LOGAN MINING MACHINERY CO. LTD.

GRAY STREET WORKS
LOCHEE · DUNDEE

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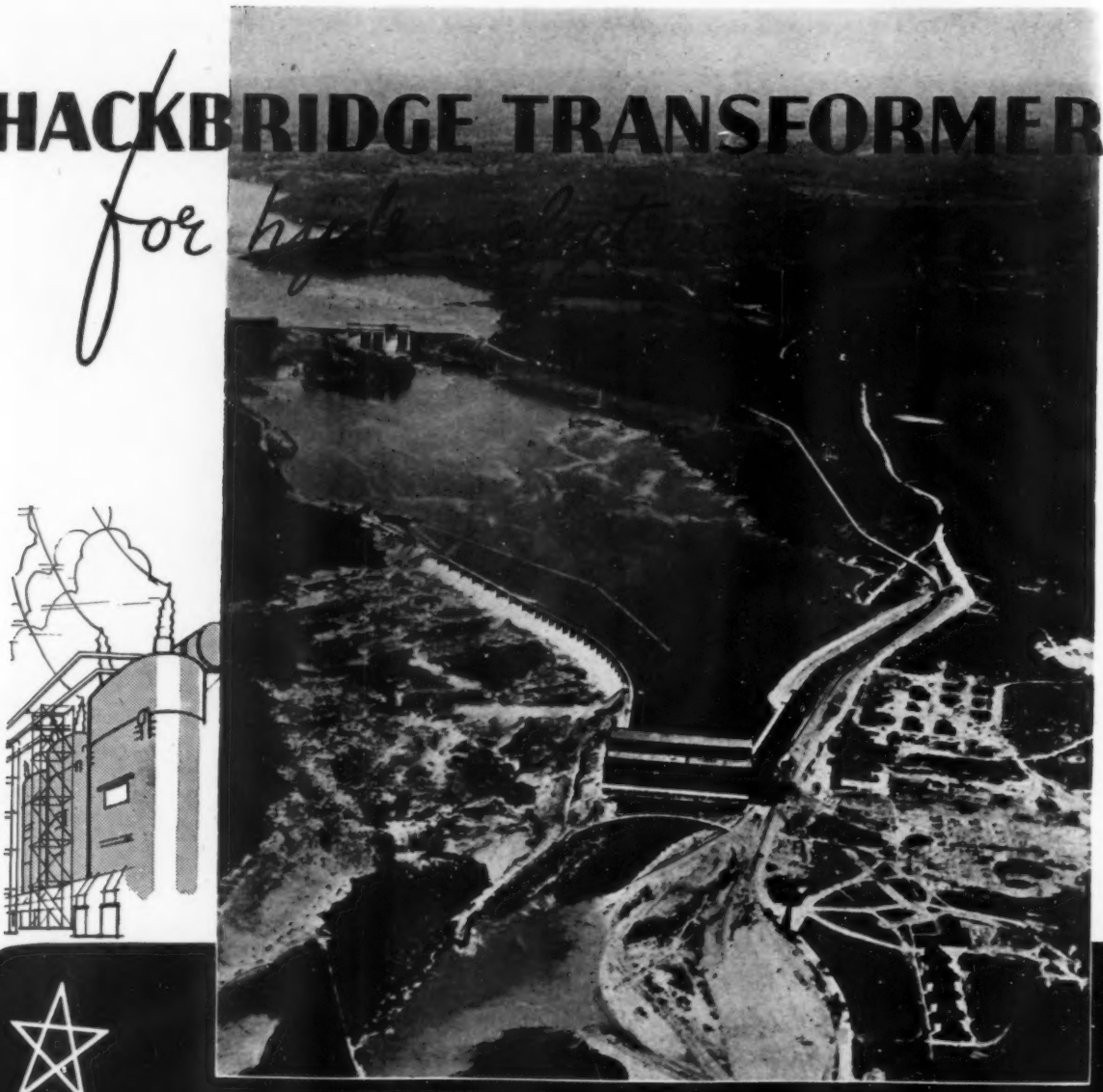
HACKBRIDGE TRANSFORMERS

for high efficiency



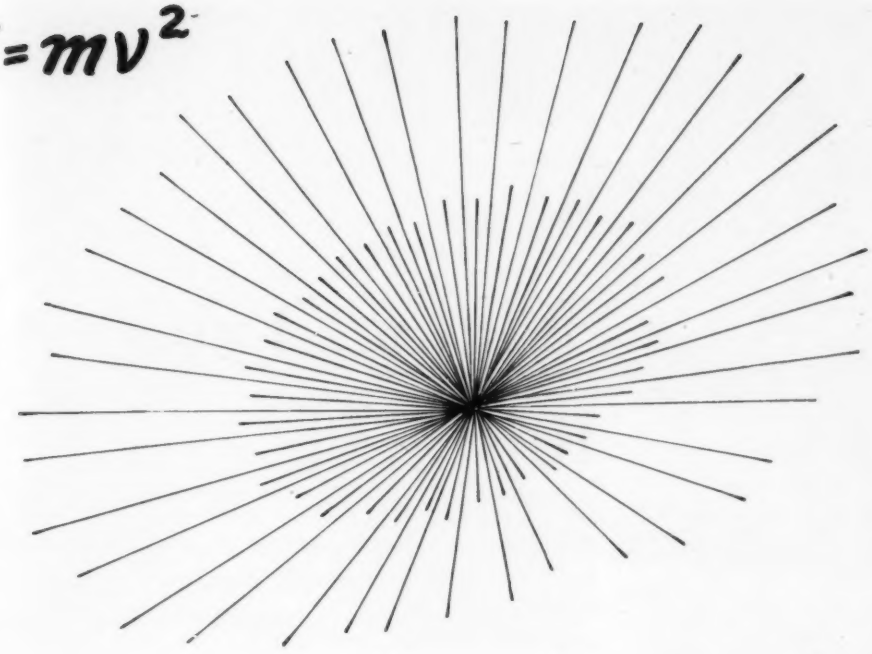
THE Hackbridge & Hewittic Electric Co. Ltd., has a long and extensive experience in the manufacture of water cooled and other types of **TRANSFORMERS**, up to the largest sizes, for hydro-electric power distribution. **HACKBRIDGE TRANSFORMERS** have established an unrivalled reputation for *reliable service* in world-wide hydro-electric installations, with operating conditions ranging from the tropical heat of East Africa to the extreme cold of Northern Canada.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD., WALTON-ON-THAMES, SURREY

Telephone: Walton-on-Thames 760 (8 lines)

Telegrams: "Electric," Walton-on-Thames

$E=mv^2$



...and the future

It is inevitable that nuclear energy will one day become a normal part of the routine of our lives, its use an every day occurrence, its control as consistently conformable to rule, and as much taken for granted, as electricity is today.

It is obvious that this control will require new forms of insulation, and undoubtedly somewhere in their construction porcelain will play a vital part . . . and it is equally obvious that only the finest porcelain will be good enough.

This being so it is certain that the stamp of Taylor Tunnicliff will be as much impressed on the future as it is upon the insulators of modern times.

TAYLOR, TUNNICLIFF PORCELAIN

TAYLOR, TUNNICLIFF & CO. LTD. *Head Office*: EASTWOOD · HANLEY · STAFFS · *Stoke-on-Trent 5272-4*
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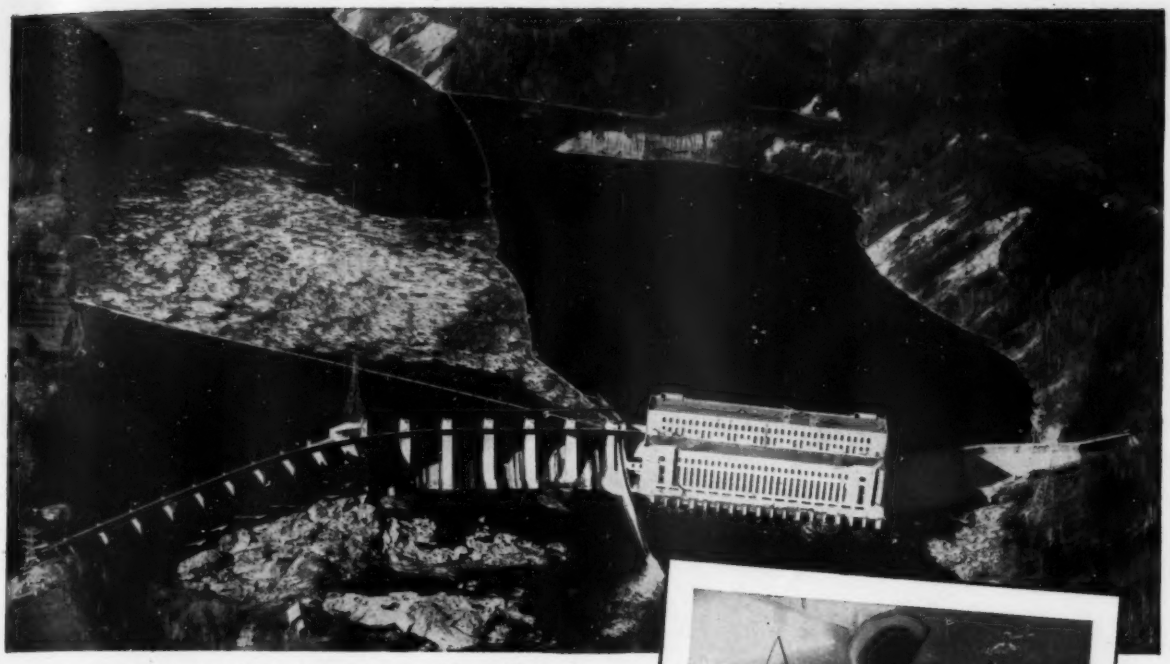

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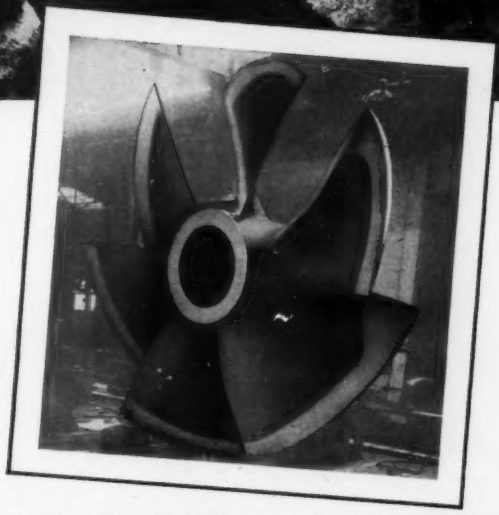

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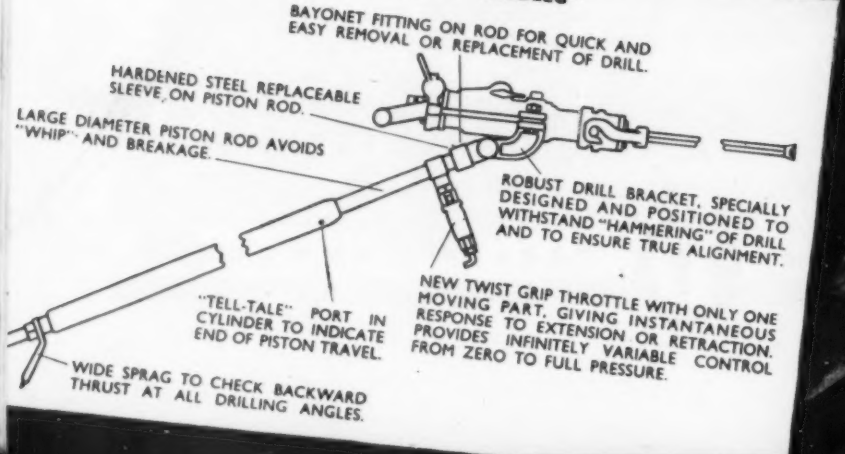
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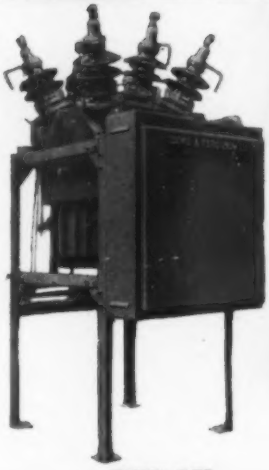

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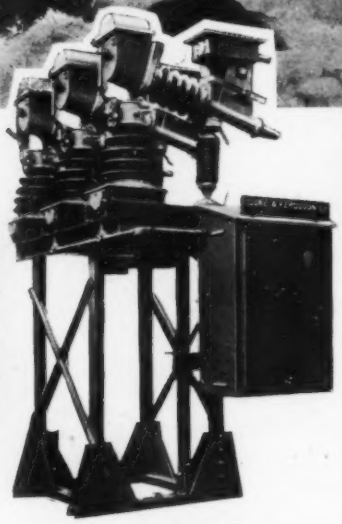

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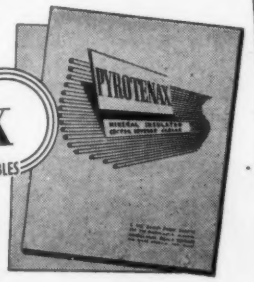

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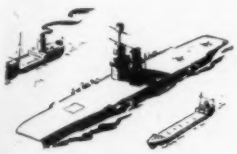

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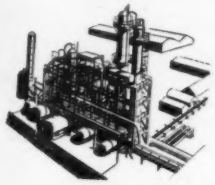

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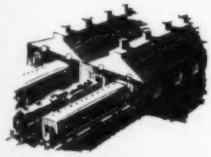

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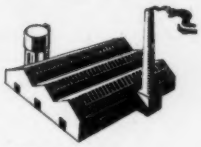

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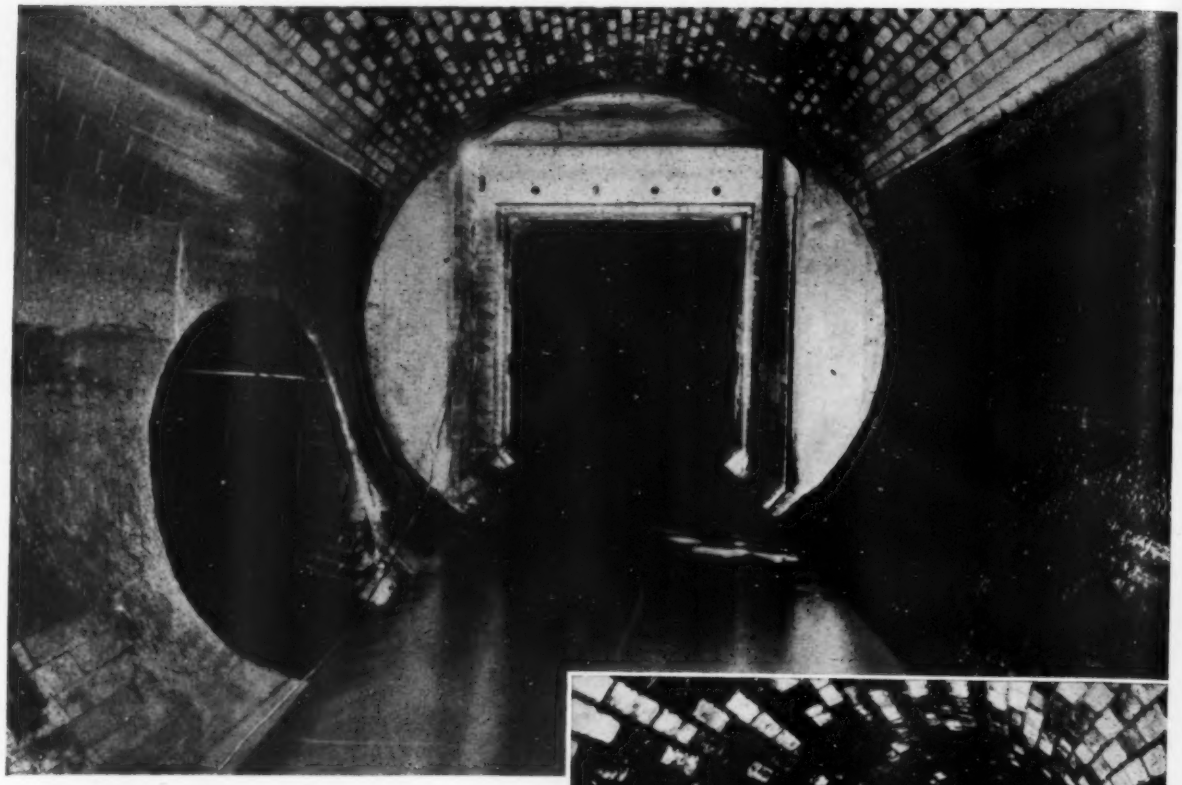
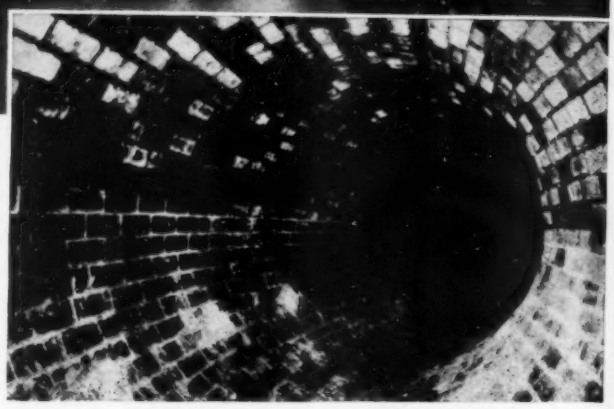


ABOVE: *Completed 10 foot Penstock Chamber looking downstream*

RIGHT: *Curve at upstream end of new sewer*



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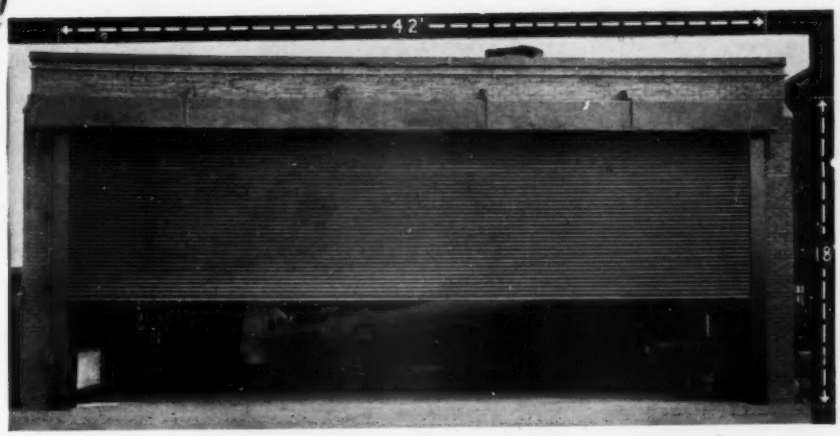

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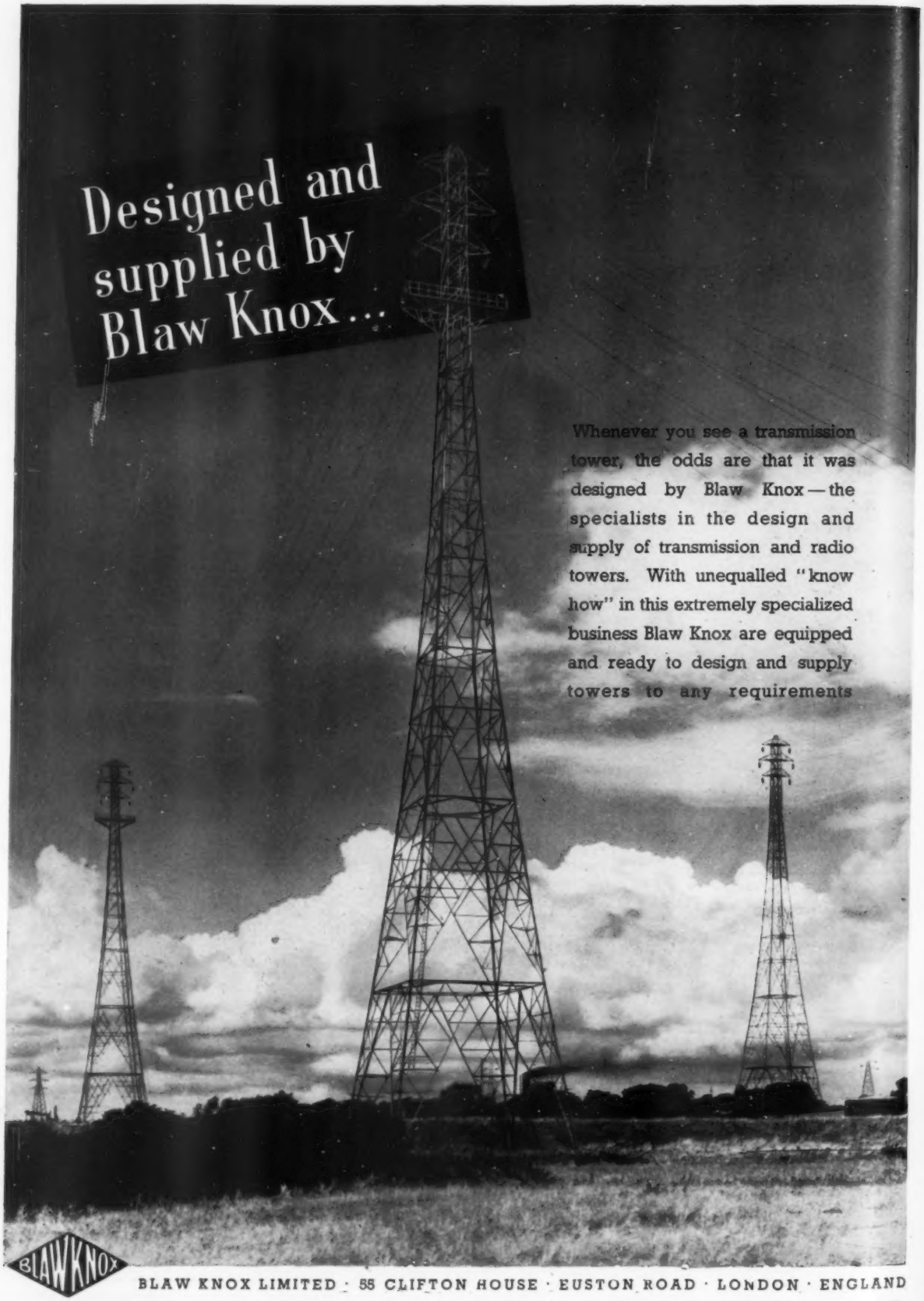
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Men and Materials

THE two great Western industrial nations, the United States and Great Britain, are accelerating their production programmes in common with other European manufacturing countries: more power is needed for more industrial output, and with a given assemblage of technical and industrial manpower and materials, it becomes vital to decide how these resources can best be used to accelerate the power-plant building programme.

For a particular expenditure in technical man-hours and in materials, which of the two main power-producing methods—hydro-electric or thermal—can give the most power? If there is a choice, which method is likely to be in the nation's best interests?

Figures given by various French engineers, including M. Nizery, show that on the basis of the amount of material needed to produce each kWh of its yearly output, the amount of ferrous material needed in a hydro-electric station is of the order of 1·41 oz. to 2·11 oz., whereas a steam power station needs about 1·23 oz. Taking the mean figure for the hydro-station, this works out at 25,810 tons of steel for a 120,000 kW station operating at 50 per cent. load factor, and 18,040 tons for an equivalent thermal station. But of the 25,810 tons for the water-power scheme, something like 22,000 tons is made up of material of a relatively simple kind, reinforcing bars and pipelines accounting for a very high proportion. For the steam station, however, only a very small part of the steel required is such as to be capable of being produced rapidly and cheaply, with little demand on skilled man-power.

The boiler plant, together with the high-precision work needed on the turbines and their associated auxiliary equipment, means that approximately 75 per cent. of all the steel needed in a thermal station will have been machined many times before use. It will also involve a large number of special alloys, the use of elaborate machine tools, and high erection costs.

Thus from the steel point of view, the authorities in a country in which there is any choice would do well to consider whether the strictly limited output of the steelworks could not be best utilised in developing hydro-electric resources. The total volume of steel required may be greater, but its cost and the demands it makes on the metallurgical experts may well be considerably less.

The other great requirement in any power scheme is cement. On the basis mentioned above, the hydro-electric station needs 102,400 tons of cement, against 25,860 tons for the steam station. The cement used in the hydro-scheme, however, is employed in providing a permanent asset in the national economy. The steam station may well be obsolete in 25 or 30 years. Further, the cement is mixed with a far greater tonnage of aggregate which is usually made—in the case of hydro-electric plants—from local rock. It is only by chance that a steam station is built alongside a quarry, and thus transportation may be a cumbersome and expensive problem to solve.

So much for materials. The manpower required for the two types of station is more difficult to assess with accuracy but the broad relationship is clear. When one considers the elements of which a hydro-electric station is composed, it will be seen that for the largest part of the project—usually the dam—there is maximum scope for mechanised labour. Once the crushers, mixers, cableways and ancillary gear have been established, the number of men employed on even the largest dams is surprising small. Moreover, there is only a small nucleus of skilled workers. Similarly, in the power station itself, the plant is infinitely simpler to build than steam plant; there are less individual high-precision units and auxiliaries; and as a final point in the man-power comparison, a hydro-electric station can be operated with a quarter of the staff needed in an equivalent steam plant, to say nothing of the thermal station having to be supported by the labour of many miners.

Where do these arguments and comparisons lead? They suggest that many countries would do well to co-ordinate, with their production programme, the maximum amount of hydro-electric development, rather than rely on additional steam stations. Man power from the pits may be needed elsewhere in time of war; and if the coal supplies fail, munitions output

—tightly geared to electrical energy—will fall at once.

In Great Britain, various governments have toyed for years with the Severn barrage scheme; three separate large-scale examinations have been made, but nothing has been done. The North Wales hydro-electric extensions have been discussed for two years and are now to await a Parliamentary Bill, which is likely to delay them as long again. In France, the tidal schemes round the Britanny coast have been planned for many years; but so far no significant work has started on site, and none is scheduled for the immediate future. On the borders of the U.S.A. and Canada, those vast St. Lawrence hydro-electric schemes have been held up for years, while new steam stations have been built, and even the Ontario hydro-electric commission erects a thermal plant.

If we must now look to our defences, we must also realise that copious electric power is a bulwark as vital as aeroplanes and destroyers. Priority must be given to the development of natural resources in the best possible way. Instead of hewing coal, transporting and re-transporting it to a distant power plant where two-thirds of its energy is thrown away, the Western nations might well consider the special advantages of water power, bearing in mind the urgency of the problem, where it readily offers its services.

Defence Power Programme

THE main portion of President Truman's new 3·9 million kW defence power programme in the United States consists of seven federal projects which would take three to seven years to complete, at an estimated cost of about $1,500 million. Six of these projects are hydro-electric. Of $462 million requested by the Corps of Engineers for construction schemes, approximately 54 per cent. will go to hydro-electric developments, and approximately 73 per cent. of the Bureau of Reclamation's $224 million construction fund is planned for five hydro-electric projects.

Among the proposed hydro-electric developments are the following: the St. Lawrence Power and Seaway scheme on the U.S. side of the river, proposed capacity 940,000 kW, at a cost of $600 million, possibly rising to $1,050 million and estimated to be available in four to seven years; Hells Canyon, with a capacity of 900,000 kW, at a cost of $433 million, estimated as being available in five years; The Dalles, with a capacity of 980,000 kW, at a cost of $326,366,000 estimated to be available in November, 1956; Ice Harbour, with a capacity of 260,000 kW, at a cost of $95,899,000, to be available in December, 1953; Old Hickory Dam, Cumberland River, estimated to cost $49,120,000 and to be available by December, 1953; Gavins Point, with a capacity of 100,000 kW, at a cost of $44,900,000, estimated to be available by April, 1956.

Bonneville Power Administration's chief engineers have also said that 40,000 kW could be provided by Portland General Electric Company's Pelton Dam and another 40,000 kW by the Box Canyon Dam of Pend Oreille, as well as 120,000 kW by the Puget Sound Power & Light Company's Rock Island development and 160,000 kW by the City of Tacoma's Cowlitz River development, estimated to be available within two years, to help meet the defence emergency.

Quebec Power Company

CONTINUED expansion of industry, particularly in Quebec City and Levis, had resulted in a 16·5 per cent. increase in the consumption of electricity and 11·6 per cent. increase in revenue last year as compared with 1949, the annual meeting of Quebec Power Company was told recently by Mr. J. A. Fuller, president.

The annual report showed that since the end of the war, the peak load on the company's system had increased by 54 per cent., to a total of 155,360 horse-power at the end of 1950, serving 94,744 electrical customers. Much residential construction was proceeding throughout the territory, and each customer is using more electricity than ever before. The report stated that business throughout the territory had been at a very high level—"a level which by all previous standards would be considered almost of boom proportions." All indications point to its continuation.

Expanding business has necessitated substantial capital expenditures for new substations, distribution lines and other installations, at a cost of $1,170,913 last year and a total of $7,447,604 since the war. During the past 18 years, the company's investment in plant and equipment has increased more than 34 per cent. and revenues have risen 153 per cent. "but, owing to increases in operating expenses and taxes, as well as to several rate reductions, the net income available for shareholders has shown only a small improvement; as a result, there has been no increase in dividends throughout this period." The belief was expressed, however, that benefits would accrue hereafter from the industrial development of the territory, and pointed to improved earnings on common shares during 1950.

Financing India's Development

INDIA'S Finance Minister, Chintaman Deshmukh, in presenting the current budget for the country emphasised that its main purpose this year is to give a good start for the next five or six years development. In the Colombo Plan they had provided for a total expenditure of Rs. 3,000 million a year, of which they thought the Centre and the states combined ought to be able to raise Rs. 2,000 million. "Examining the figures for the last two years," he continued, "I find that we have fallen far short of that and I think the deficit will be of an order of about Rs. 1,000 million. That is to say, we have been running our development on deficit financing to the extent of about Rs. 1,000 million.

"This time I think we will probably find our total deficit may be of the order of Rs. 500 million or 600 million and if conditions improve, then I think we shall have discharged our part of the burden. We shall have raised Rs. 2,000 million for our development plan."

Referring to river valley projects in the country, he said their conception was very sound as the projects would be the cheapest way of increasing the value of land, especially after partition. Those projects, he said, would be a lasting and permanent investment. They provided one of the most fascinating fields of endeavour in India for which money must be found.

Sweden's Transmission Plans

IT is officially announced from Sweden that the Swedish Waterpower Board is to construct a new 380 kV power circuit which will run from Skane to Hallsberg in Central Sweden, where it will be linked with the circuit from the new Harspranget Power Station in the north. This third high voltage line will pass through Gothenburg, but it has not yet been decided whether it should be laid as far south as Malmo or stop in north-western Skane, Sweden's southernmost province. It will have a length of 250 miles and will cost about 42 million kroner. Designed mainly for Swedish internal needs, it may also be used, if need be, for exporting power from Norway to Denmark by way of Sweden, which is now being discussed by the three Governments.

The 380 kV volt circuit between Harspranget and Hallsberg will be opened shortly, though sections of it have been used for some time. The second circuit at this voltage is under construction and will run from Angermanalven, a river in the north, to Enkoping, in Central Sweden.

New Fertiliser Plant

WORK is now virtually completed on the heavy constructional side of the fertiliser plant at Sindri, in the Indian province of Bihar. Three riverside pumps, each capable of delivering six million gallons of water daily, are being put into commission. The power house in the fertiliser factory, which starts operation shortly, is one of the most modern in the world. With an installed capacity of 80,000 kW it will not only supply power and steam for the processing work of the factory, but also the bulk of power to the Damodar Valley Corporation grid to the extent of 20,000 kW for distribution to industrial consumers. The power house is designed for further extension and provision also has been made for complete duplication alongside the existing site.

Technical Aid in Asia

IN its first two months the Technical Co-operation Council of the Colombo Plan has received well over 130 applications for technical assistance from Ceylon, India and Pakistan. Sixty-nine requests call for 129 experts; 66 desire training courses for 230 people, and one is for equipment. Australia has offered 150 fellowships and scholarships, Canada various degrees of training in agriculture, engineering and forestry, while the United Kingdom is ready to give opportunities for training over a very wide field. No definite offer has come from the United States, which has its own programme for supplying aid and has liaison with the Colombo Plan. The Council particularly expresses the hope that non-Commonwealth countries will make full use of the facilities provided by its bureau.

Leaders for Rhodesia

FINANCIAL reasons for Rhodesia possessing a university of its own are now being put forward in the country, which stands to benefit greatly from the big power and other schemes now in preparation to serve the growing industry of the areas. It costs about £250 a year to keep a student in a university in South Africa, and at present something like £130,000 is leaving Rhodesia in this way each year, or about £1 per head of the European population. To-day Rhodesia has about 400 students in the universities of the Union. But the European population has trebled during the last quarter of a century, and at that rate the population of the colony would be a million before the end of the century. Funds for the suggested Rhodesian University Association now total nearly £60,000, of which almost £15,000 has been collected during the current financial year, including four figure donations from some leading firms.

New Scottish Scheme

THE North of Scotland Hydro-Electric Board has just published their Kilmelfort Scheme (Constructional Scheme No. 61) which will add nine million kWh of electricity annually to the power available in Western Argyll. The scheme will utilise a catchment area of 11 square miles with an annual rainfall of approximately 74 inches.

Loch na Sreinge will be impounded by a small dam at its northern end. An aqueduct will lead the water into Lochan a'Bhailis and Loch Tralaig. Loch Tralaig itself will be impounded by a dam on the River Oude and will provide the main storage reservoir of the scheme with a capacity of 133 million cubic feet. Water from Loch Tralaig will be released down the River Oude to a small headpond, to be formed in the Pass of Melfort by a dam across the River Oude, from which it will pass to a generating station containing one 3,000 kilowatt turbo-alternator operating under a gross head of 365 feet.

Russia's New Canal

CONSTRUCTION of the canal, the second biggest in Russia, linking the Volga and Don rivers, has been the subject of wide publicity throughout the Soviet during the last month or so. This 62 mile link between two great waterways will be used for the production of electric power as well as for irrigation of great stretches of country. It was begun before the war, but the German occupation of the entire region prevented its development. Now completion is well on the way. When eventually opened it will form the final link in a great chain of waterways joining the main seas in or bordering Russia—the White, Baltic, Caspian, Azov and Black. The longest of these canals is the Moscow-Volga (about 80 miles).

Marion Excavators

A LICENCE recently granted to John Blackwood Hodge & Co. Ltd. by the Marion Power Shovel Co., of Marion, Ohio, will permit the manufacture of Marions in the United Kingdom, commencing immediately. The production of these excavators in Britain will enable users throughout the sterling area to buy a full range of excavators, draglines and cranes for sterling—an enterprise which will be of benefit in saving dollars. The Blackwood Hodge Organisation will be responsible for the distribution and servicing of the Marions in Britain, India, and many territories in Europe, Africa and Asia. Delivery of the first machines is expected in about 18 months' time.

Training of Hydro-Electrical Engineers

This article by Professor J. A. Harle, Head of the Electrical Engineering Department, University of Alberta, discusses the fundamentals of the training which a hydro-electrical engineer should receive and suggests a curriculum for a four-year university course.

ENGINEERS for hydro-electric work can only be viewed as adequately trained if their academic work at a university is supplemented by a broad experience on an electrical undertaking with hydro-electric generation. A number of undertakings of this type exist in the U.S.A., Canada, Norway, Sweden, Switzerland, France and elsewhere but it must always be borne in mind that power generated by steam or gas-turbine plants may be used to supplement large hydro-electric networks. The situation will therefore be such that the men in top positions will require to have an adequate background of both steam and hydro knowledge and experience. With relatively few exceptions, hydro generation takes place at distances remote from the major power-consuming centres; hence, the transmission of power over relatively long distances is a vital part of hydro-electric engineering. As the various sites suitable for hydro development are exploited, sites progressively more difficult or more remote from consuming centres must be considered, so that the main responsibility of men in top positions will be to decide economic problems of generation and transmission, taking into account a number of different engineering techniques. By having suitably trained men sound decisions will be made, but only after correct allowances are made for the various technical limitations that usually arise when trying to make major decisions. Frequently when decisions involving economic considerations are to be made the financial world tends to view them as a simple matter for the economist or financier; hydro-electric development, however, has many technical limiting features that prevent such a simple course from being adopted. It is for this reason that the hydro-electric engineer must have a very sound training, and perception in both economics and engineering if he is to go to the top of the ladder in his profession.

If one considers the man to train for this field he must essentially be of a type that can respond to a training in principles and broad issues rather than simply one who can become a technician. Personality is extremely important during the mid-period of his life, and, having regard to the large amount of capital that has to be raised to build such projects as hydro-electric schemes, it is essential that the top men should be of sound character and have attractive personalities. While the present tendency for such large projects is for a commission or state authority to be responsible for the broad planning, this does not remove the necessity for the above stipulation.

The academic training of the individual who desires to enter this field should be on the broadest of lines.

The entry could be by way of either of two branches of engineering, civil or electrical and, provided the student is the correct type, he would have a suitable groundwork from which to study the more advanced engineering techniques that he required as he progressed up the ladder. A sound grounding in English, obtained either at school or university, would be essential, as there is a direct necessity to present complex problems in simple language.

General studies must include:

Physics—dealing with properties of matter, heat, light, sound, magnetism and electricity.

Chemistry—inorganic chemistry.

Mathematics—covering algebra, analytical geometry, calculus—including functions of two or more variables, space loci, determinants and matrices, differentation, integration, series, differential equations, complex numbers, vectors, elliptic integrals, Fourier series and analysis, vector analysis, line and surface integrals and an introduction to the elements of complex variables.

Mechanics—Fundamental principles involved in kinemetics and dynamics of particles, centres of mass, plane statics, Hookes law, law of restitution, simple harmonic motion, projectile motion, moments of inertia, virtual work, stability, catenary problems and friction.

Principles of political economy.

Elementary geology.

Elementary mechanical drawing—including descriptive geometry and appropriate engineering drawing.

Surveying—including mapping and field work.

Engineering materials — including strength of materials, materials testing, and statics.

Elements of mechanical engineering—including thermodynamics, heat engines, internal-combustion engines, steam engines and steam turbines, steam flow and machine design; this course would be supplemented by work in an associated mechanical engineering laboratory.

Hydraulics—principles of fluid motion, including laboratory work.

If the student is graduating in civil engineering, there must also be included studies in:

Elements of soil mechanics, including work in soil-

Opposite page: Cascade plant of Calgary Power Ltd., showing canal, wood stave pipe line, surge tank, power house and tailrace. The dam is not shown, being nestled in the more remote branch of the lake to the left of the picture

mechanics laboratory—vital to an understanding of hydro-electric site considerations.

Foundation principles and design, design of earth structures.

Theory of structures and structural design, including steel, concrete, etc.

Hydrology and water-supply engineering.

Engineering construction, including quantity surveying and organisation of construction forces.

Elementary electrical engineering.

Materials of construction.

Water-power engineering.

Transportation and sewerage.

All of these studies are fundamental for the civil-engineering student intending to enter the hydro-electrical field.

If the student is graduating in electrical engineering, there must also be included a sound grounding in the principles of electrical engineering and electronics, including a study of electrical machinery and circuits. Thorough courses of instruction must be taken in the following:

A.c. machines including alternators, synchronous motors, induction motors, transformers, switchgear and other types of electrical machinery. Extensive laboratory work must be an important feature of this course as well as a course in electrical machine design.

Electrical power transmission including studies in long-distance power transmission, system transients, function of relays, control of power transmission, high-tension phenomena. Courses in electrical measurements and an advanced review of the fundamentals of electrical engineering are also desirable. Power-plant design and layout is an important item in a suitable course. A course in electrical communications is also advisable and a study of the applications of electrical power is also needed to round off the course.

Electrical-engineering graduates should see the constructional work on a hydro-electric site including survey work during one vacation and, if possible, should spend one or two vacations in a works, preferably where heavy electrical machinery is being built.

Following this the student should preferably enter a hydro-electric utility company as a trainee or student-apprentice and should go through the various departments of the concern with a view to gaining an appreciation of the structure of the organisation.

It is only at this stage that the real training of the hydro-electric engineer can be regarded as having started. As he progresses through the organisation, he must study each phase of the work, summing up the reasons for the methods adopted and privately analysing whether alternative methods would be preferable and more economic. The young engineer should become a member of the appropriate professional institution and, in many cases, of other institutions if his chosen field can be covered only in that way. He should read and study the various publications covering electrical, mechanical and civil engineering and, by that method, learn new techniques. Another essential must be to read all published work on water-power schemes subscribing to specialist publications such as *Water Power* and *L'houille Blanche*, but, above all, he must consider in his reading not only the more attractive technical features but also the economic aspects. His later life will be more and more taken up with economic and administrative work.

It would be beneficial in many instances if arrangements could be made by his firm for him to obtain at least a year's experience in another undertaking or, alternatively, for him to travel and consider the design, operating techniques, etc., of overseas undertakings. This latter course would be particularly beneficial if it could be arranged just before the investigation of major extensions, as it is just then that the latest ideas of economic construction are reflected into a new project. Further training may even involve the individual working for a few years in another organisation such as a large consulting engineer's office specialising in hydro-electric work.

The University of Alberta does not make special provision for hydro-electric training as such but the course content for the civil engineer and the electrical engineer are arranged to give a sound grounding from which to train for this work. Courses for a bachelor's degree in civil engineering and electrical engineering are of four years duration in which the first two years are arranged to be common and during which the basic sciences and mathematics are studied as shown in the accompanying tables.

FIRST YEAR ENGINEERING

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.
Inorganic Chemistry	3	3	2	3
Science and Engineering	1	—	—	—
Mechanical Drawing	—	3	—	3
Descriptive Geometry	2	3	2	3
Element. Math. Analysis	2	2	2	2
Element. Mechanics	3	—	3	2
Physics	3	2	3	2
Surveying	—	—	2	—
Survey Field Work*	—	—	—	—
Physical Education	—	2	—	2

SECOND YEAR ENGINEERING

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.	hr. pr. wk
Statics	2	—	2	—
Mapping	—	3/2	—	3/2
Engineering Materials	2	—	2	—
Strength of Materials	2½	3/2	2½	3/2
Engineering Drawing	1	3	1	3
Geology	3	3/2	2	3/2
Calculus	3	—	3	—
Mechanics	2	2	2	—
Physics	3	2	3	2
Survey Field Work	—	—	—	—
Applied Astronomy	—	—	—	—

* 1 month Field Work given in April for both 1st and 2nd year.

CIVIL ENGINEERING THIRD YEAR

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk	hr. pr. wk	hr. pr. wk	hr. pr. wk
Elements of Soil Mechanics	—	—	2	—
Hydraulics	2½	3/2	2½	3/2
Theory of Structures	—	—	3	—
Elements of Struct. Design	2	3	2	3
Engineering Construction	2	3	—	—
Hydrology	2	3	—	—
Water Supply Engineering	—	—	2	3
Elements of Elec. Eng.	2	3/2	—	3/2
Elements of Mech. Eng.	2½	3/2	2½	3/2
Principles of Political Ec.	3	—	3	—

The third and fourth years differ in that more specialist training is given in the respective fields.

CIVIL ENGINEERING FOURTH YEAR

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.
Foundations	2	—	2	—
Design of Earth Structures	—	—	2	—
Soil Mechanics Laboratory	1	3	—	3
Theory of Structures	3	—	3	—
Structural Design	2	3	2	3
Materials of Construction	2	3	—	3
Water Power Engineering	—	—	3	3
Land Transportation	2	—	2	3
Sewerage	2	3	—	—
Strength of Materials	—	—	2	—
*Option of Thesis	3	—	3	—
Theory of Structures	3	—	—	—

* To be approved by the Department of Civil Engineering, equivalent to 3-0-3-0.

ELECTRICAL ENGINEERING THIRD YEAR

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.
Hydraulics	2	3/2	2	—
Elements of Mech. Eng.	2½	3/2	2½	3/2
Principles of Elec. Eng.	3	5	3	5
Machine Design	2	—	2	—
Fundamentals of Eng. Electronics	2	—	2	3/2
Advanced Calculus	2	—	2	—
Electrical Physics	2	3	2	3
Principles of Pol. Ec.	3	—	3	—

ELECTRICAL ENGINEERING FOURTH YEAR

SUBJECTS	First Half		Second Half	
	Lectures	Lab'tory	Lectures	Lab'tory
	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.	hr. pr. wk.
Electrochemistry	—	—	3	—
Principles of Elec. Eng.	3	5	3	5
Electrical Power Transmission and Distribution	2	—	2	—
Electrical Machine Design	1	3	1	3
Electrical Communications	2	3/2	2	3/2
Problems	—	2	—	2
Fundamentals of Electrical Engineering	2	—	—	—
Power Plant Design	—	—	2	—
Electrical Instruments and Applications of Electrical Power or	3	—	—	—
Short and Ultra-Short Wave Radio	2	3/2	2	3/2

The vacation lasts from about the beginning of May to the end of September, and hence summer experience of adequate duration can be obtained. The majority of students use their summer earnings to pay their way, or at least part of their way, through a university course, and the National Employment Service, with the help of the university faculty members, facilitates the obtaining of suitable employment. Those interested in hydro work usually obtain employment with the Calgary Power Company who operate a group of hydro-electric stations, and a great deal of useful experience has also been obtained by other students working on their new constructional work. Other students can obtain experience in Eastern Canada with the Hydro-Electric Power Commission of Ontario and other systems.

Conclusion

It will be obvious from the foregoing that no student can train himself to be a leader in hydro-electric engineering but can only be adequately trained by his own efforts and those of his employers. Naturally this involves the careful selection of the individual, in giving him experience and responsibility at appropriate periods in his mental development, such a training being frequently an investment on the part of the employers. Sometimes it might appear a total loss to them if he leaves, but all organisations must face a training responsibility for their side of engineering in that, while they lose their trained man, they may gain the fruit of someone else's training and, in the long run, the necessary leaders have been produced.

CORRESPONDENCE

PELTON OR FRANCIS TURBINES FOR HIGH HEADS

To the Editor of WATER POWER

Mr. Raymond C. Collet discusses in an interesting article under the above title the comparative merits of Pelton and Francis turbines for heads ranging between 300 and 400 meters.

I readily agree with Mr. Collet in his conclusion that in most of these cases the Francis turbine is to be preferred. In my opinion the range between 400 and 500 meters may also be considered for turbines of higher outputs.

Mr. Collet's remarks on the maintenance of the Francis turbine is, however, unfair to this type, as the figures given for actual operating time, inspection and upkeep are exceptionally unfavourable in the light of Norwegian experience, and may give the reader a false impression of the possibilities of a Francis type of turbine.

The experience gained with high-head turbines built by Norwegian engineers shows very little maintenance to be required. As an example it may be mentioned that a plant consisting of two Francis turbines of 60,000 h.p. each and with a mean net head of 397 m. has been running since January and October 1949, without any appreciable wear. No repairs are furthermore expected in the foreseeable future.

No Francis turbines are running in Norway today with net heads above 400 meters, but three are now under construction designed for a max. net head of 444 meters and developing 70,000 h.p. each. Based on the experiences gained with the 60,000 h.p. machines mentioned above the builders are convinced that the maintenance involved will be an item of minor importance, particularly as the units are larger.

The adoption of moderate speeds keeps wear and tear at a minimum and for that reason the turbine speeds of the two plants were fixed at 500 revs. per min. This moderate speed, in the builders' opinion, is of the utmost importance in keeping maintenance expenses low.

ARNE FISMEN.

A. S. Kvaerner Brug,
Oslo,
Norge.
March 14th, 1951.

Typical Installations. This admirably produced booklet, which has been printed in Spanish and French in addition to English, describes different types of plant built by Ernest Newell & Co. Ltd. during the past ten years or so. Throughout the war a certain amount of special equipment was constructed by this firm, but their normal products include crushing, grinding, washing, screening, and handling plant.

Very High-Voltage Transmission

Dr. S. Whitehead discusses the value of co-operative research in relation to this subject, which is of growing economic importance, and refers to the work of the Electrical Research Association.

LIKE other good things, co-operative research has its strengths and its limitations. It provides a co-ordinated and, where necessary, concentrated attack on common problems and avoids costly and frustrating duplication. Its limitations become apparent in actual production and operation where individual designs and methods are being developed necessarily by the individual concerns responsible for them, although a research association may occasionally proceed to a prototype of quite large scale. Transmission of electrical energy at very high voltages is a great engineering project to which the contribution of electrical science, though so vital and fascinating, is volumetrically small (Fig. 1). The realisation of the installations means often a choice between individual designs and methods all based on similar fundamental principles. Accordingly the Electrical Research Association has been concerned less with the design of particular equipment than with user problems, with the elaboration of basic principles and with materials and elementary components.

In the choice between a.c. and d.c. the Electrical Research Association has made an analysis of technique and economics, based on existing information, concluding that d.c. has a case when large blocks of power have to be transported over a simple link for a considerable distance, say, 350 miles, but possibly much less. A full-scale trial depends mainly upon one or more concerns taking some chance on the high-voltage and high-power converter equipment. In the meantime several problems on the control, regulation, stability, operation (especially starting), design and protection can be studied on a small scale, so the Association has installed a miniature d.c. system, working at 1,000 volts and 10 amperes with artificial networks to simulate transmission lines and loads (Fig. 2). The equipment has already yielded important results.

Some specific points on the stability of long a.c. lines have occupied attention but the main effort is the production of an a.c. network analyser (Fig. 3) suitable for a very wide range of problems. It is hoped in small bulk to cover a frequency range of 100 to 1, much greater than existing analysers, which will permit the study of variable operation and transient response as well as the determination of natural frequencies and the characteristic values of functions in general which are capable of representation by electrical analogues.

Apparatus for metering and control becomes difficult at very high voltages. The capacitor transformer may fill the role of a potential transformer and new designs are being tried. The conventional current transformer is satisfactory in performance but so costly that when it cannot be incorporated in types of circuit breaker more suited to very high voltages, in the manner possible in a bulk oil circuit breaker, its influence on the design of equipment may be undesirable. Since the cost is in the insulation, it is necessary to devise either novel methods of isolation or entirely new principles for measuring or using the line current.

Fig. 1. The Tidd 500 kV test project; view of transformers and line from observation booth (Taken from C.I.G.R.E. Paper No. 415 by I. W. Gross and C. F. Wagner)

High-voltage operation increases the thickness of the insulation of power transformers. This and the ever increasing ratings of individual units accentuate the problems of heat dissipation and mechanical stability under electromagnetic forces, both of which are being actively pursued. Methods of protection are also important, such as the gas-operated relay; also the question of maintenance, for example, the deterioration of oil.

In the early days of circuit-breaking, the arc was drawn so far that, after extinction, the gap would withstand relatively high voltages. E.R.A. researches (Fig. 4) on circuit-breaking showed how the arc could be rapidly extinguished with only a small travel of the contacts. However, rapid extinction may require provision for large inductive voltages, so in a way switchgear progress has tended to solve its own high-voltage problems. Indeed, adequate primary insulation and auxiliary isolating switches may be all that are needed but very high voltages are often accom-

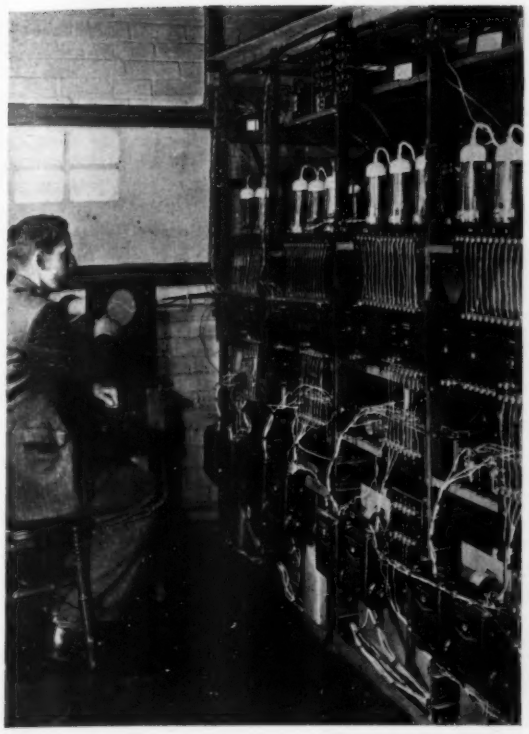


Fig. 2. E.R.A model high-voltage d.c. system: on the top shelf are meters, on the second thyratrons representing two banks of rectifiers (2 × 6 valves) and two banks of inverters (2 × 6 valves). Below is control gear and at the bottom the a.c. switchgear. Behind but not visible, are banks of capacitors, inductors and resistors representing lines and loads

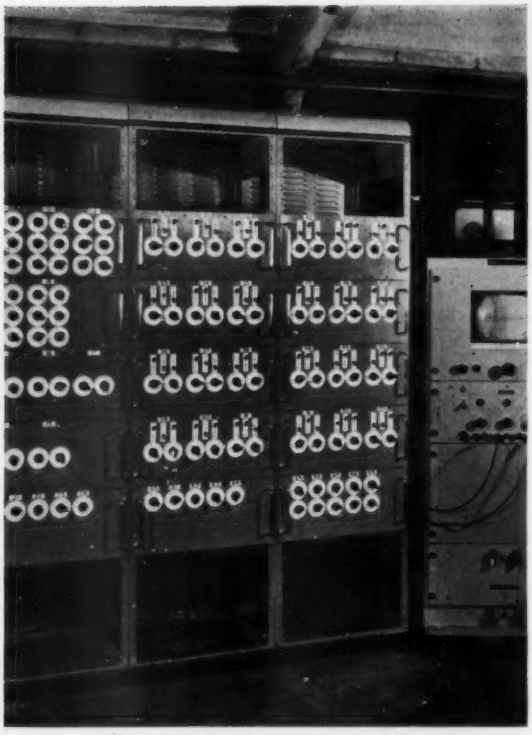


Fig. 3. Part of E.R.A. pilot network analyser with oscillograph for transient studies

modated by series multiple breaks. This method involves some fundamental problems which are the subject of co-operative research. One of the main results of E.R.A. research has been the development of the gas-blast circuit-breaker, so that work on this links up with the ancillary but important question of the current transformer already mentioned.

One result of the Association's research on lightning is the fundamental importance of the lightning current. When the system voltage exceeds 33 kV only direct strokes need be feared. Since the impedances of towers and lines do not increase much with line voltages, neither will the voltage due to lightning, so that the danger of lightning surges is less on higher voltage systems. Probably a 500 kV line provided with an earth wire is nearly immune from this trouble, but the cost of damage demands a fairly accurate estimate of risk. This applies *a fortiori* to switching surges, which in some cases can build up a multiple of the line voltage, subject to the over-voltage protective gear. Thus investigations on surges, their prediction, abatement or avoidance, have their part to play (Fig. 5).

Normally a very high voltage line would follow a route through country as empty as possible so that radio and telephone interference would be minimised by the most effective method, namely separation from other services. On the other hand, the project itself might have arisen from the need to link areas separated by natural barriers and it is possible that the line might have to run through a narrow valley, followed perforce by telecommunication systems. This yields a difficult situation and the E.R.A. has done a great deal of work on this matter. Interference to broadcasting and television will usually arise from the height and length of a line and the discharges from it. This source of trouble is hoped and believed to be unlikely; it would be most vexatious if it happened, and would demand specialized knowledge for its solution. Much more serious than all the foregoing would be the harmonics from d.c. transmission at high voltage, in normal and especially in abnormal operation. The problem has been studied and the necessary measures would have to be taken seriously into account in examining any project.

All engineering depends on materials and elementary components or assemblies of materials. This is especially true of electrical engineering where progress has been conditioned by the development and supply of highly specialised materials. For this reason the E.R.A. has always devoted a substantial part of its resources to research on materials and components. Very high voltages require a corresponding level of insulation. Many years of co-ordinated research have enabled the Association to analyse and assess, sometimes quantitatively, the processes of breakdown of insulation. Intrinsic breakdown is electronic and can be predicted from structure. It applies mainly to breakdown under surge voltages. A margin must be

allowed in practice for the defects, only slightly investigated so far, apparently inescapable in insulation on a practical scale and especially for great thicknesses. Heterogeneous insulation also requires a margin and a research is in progress on the impulse electric strength of combined and composite insulations. Insulation design is largely determined by the impulse voltage test so that the margin to be observed on the intrinsic electric strength for the withstand surge strength is an important and nice choice. The margin of impulse test over working voltage depends upon over-voltage studies already mentioned. But the breakdown mechanisms for sustained voltages differ essentially from those with impulses, so that when the over-voltage ratio is reduced for very high voltages these breakdown mechanisms become more important. In the absence of lateral cooling (*i.e.* when the heat flow is parallel to the electric field) there is a maximum voltage for thermal stability however great the thickness. When the working voltage comes into this region either some ingenuity is needed to obtain enough lateral cooling or low-loss materials must be used. The avoidance of breakdown by external or internal discharges is harder as the voltage increases, partly because voids and high surface stresses are more troublesome to eliminate with greater thicknesses and also because discharges at points and edges tend to depend on the voltage and not on the average voltage gradient. A consequence has been the development of insulation using high-pressure gases and liquids as immersion media. Electrochemical stability is important because with very high voltages there is potentially a greater voltage which can be concentrated on part of the insulation by a distorted voltage distribution. For these, among other reasons, interest attaches to an attempt to find a method of routine testing, more reliable than the d.c. leakage, the a.c. power-factor or voltage-distribution tests, by which incipient breakdown may be recognised and faulty gear taken out of service before failure.

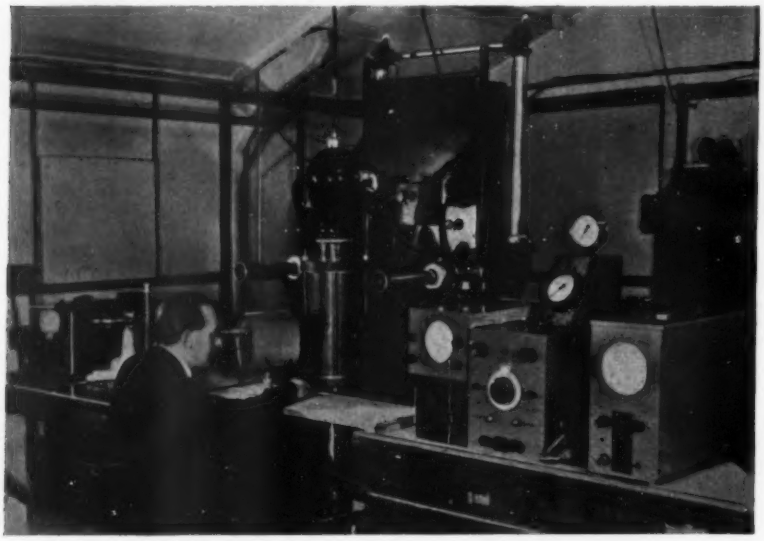


Fig. 4. Fundamental physical research is needed in circuit-breaker research and the view shows a room in the E.R.A. switchgear department. In the centre is a stabilised arc in a gas chamber with a stroboscope in front. On the right are oscillographs for recording electrical and other phenomena and on the left a spectroscope with photo multiples for observing transitory spectra to follow the behaviour of electrons and atoms during the development and distinction of the arc

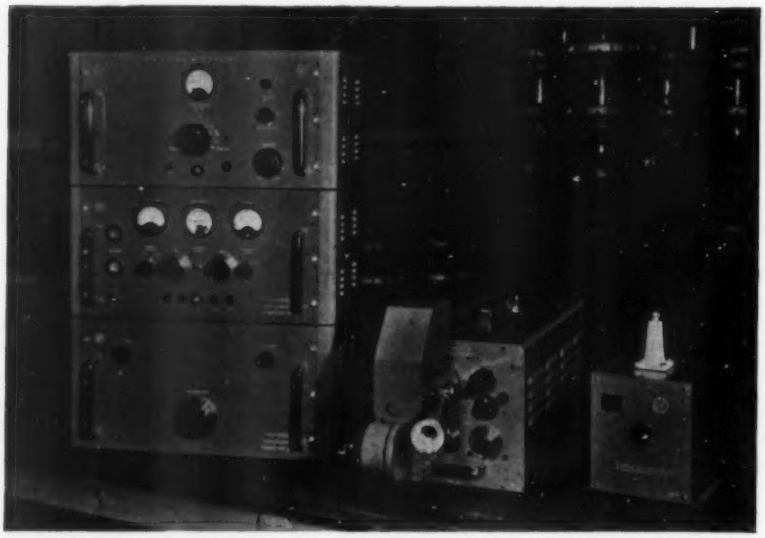


Fig. 5. Surge measurement and testing: control equipment for E.R.A. impulse generator (lower stages in background), high speed oscillograph with 10 kV sealed-off tube, and surge counter on right

The foregoing paragraph mainly refers to solid and liquid insulation and explains why high-voltage systems depend upon air for insulation whenever possible. However, with a.c. the clearances in air increase rapidly when very high voltages are reached, which also renders difficult the design of protective gaps. Apart from breakdown, corona forms more readily at higher voltages so that to reduce corona a single conductor has to be uneconomically large for the current it has to pass. This has led

to multiple conductors in which a few single conductors are arranged geometrically to relieve the electric stress and reduce corona without an excessive total cross-section of metal in the group. There are many other features but enough has been said to justify the Association's extensive research into the fundamental and practical characteristics of gaseous discharges.

One research worker has taken a step beyond terrestrial thunderstorm into speculations about cosmical discharges in the sun and stars. Let not this be regarded as too fanciful. Research must always envisage conditions extrapolated a good deal beyond the immediately practicable, and the very high voltages now seriously considered for transmission may perhaps be approaching the region of the limiting voltages which can be applied in the usual way to extended conventional types of conductor.

Shin and Orrin Schemes

THE North of Scotland Hydro-Electric Board announce their Shin Scheme (No. 32) which will use the waters of Loch Shin and tributaries, the River Cassley, the River Brora and other streams in the County of Sutherland for the annual production of about 167,000,000 units.

The scheme, which will harness the water power resources of an area of 250 square miles, is estimated to cost approximately £8,000,000. The work involved includes the construction of one main and five subsidiary power stations with a total capacity of 44,000 kilowatts.

The main power station, which will be built on the north shore of the Kyle of Sutherland near Linsidemore, will have a capacity of 25,000 kilowatts. A five miles long tunnel will feed water to this station from Loch Shin which, by a dam 1,125 feet long and 39 feet high at Lairg, will be enlarged to provide a storage capacity of 10,300,000,000 cubic feet (equal to a reserve of 50,000,000 units of electricity). Provision will be made for the ascent of salmon above this dam.

One of the subsidiary power stations will be built near West Shinness Lodge on a new bay formed by the enlargement of Loch Shin. It will draw water from the River Tirry and tributaries. The generating plant in the Tirry station will have a total capacity of 1,750 kilowatts.

Further west and also on the north shore of Loch Shin is the Fiag station with a capacity of 1,000 kilowatts. It will be fed by water led by aqueduct from the River Fiag.

The Cassley station on the southern shore of Loch Shin near the western end will use water brought by tunnel from the upper Cassley and streams which feed it. The available head is 371 feet and the station's capacity will be 3,750 kilowatts.

There are two subsidiary developments to the north-west of Loch Shin. One consists of a dam to enlarge Feur Loch, an aqueduct and a power station with a capacity of 1,000 kilowatts situated on the southern shore of Loch Merkland near Garvault. The remaining station, Ben Hee, is to be on the opposite side of Loch Merkland and will have a capacity of 5,000 kilowatts. It will be fed from a storage loch formed by a dam to join three small hill lochs, Loch an Islaird, Loch ant-Seilg and Loch a Tuim Bhuide.

The North of Scotland Hydro-Electric Board also published recently details of their new diesel generating station in Wick (Constructional Scheme No. 59) which will more than double the existing generating plant capacity in Caithness. This station will have a total installed capacity of 3,600 kilowatts consisting of six 600 kilowatt diesel generating sets. Its construction, which it is estimated will cost £157,120, has been made necessary by the great rise in the demand for electricity in the County.

The Board have already increased the capacity of their Wick generating station from 800 kilowatts to 1,880 kilowatts, and their Thurso generating station from 743 kilowatts to 1,043 kilowatts, but as a result of the progress made on the distribution scheme for the County, the additional plant is insufficient to meet the growing electrical requirements.

Orrin Scheme

The Orrin scheme (No. 29) will develop the water power of the River Orrin in Ross-shire to produce 18,000 kilowatts of power and an annual output of 74,000,000 kWh. This scheme represents the third stage in the development of the River Conon basin which will have six generating stations and seven main dams. The combined capacity of the stations in this group will be about 107,000 kW with an annual output of about 442,000,000 kWh. The first stage, the Fannich scheme, went into operation in November 1950 and helped to meet the heavy demands of the Highlands for electricity in the past winter. The second stage is the Glascarnoch-Luichart-Torr Achilty scheme upon which work is just starting.

The estimated cost of the Orrin scheme is £3,500,000 and the proposed works include a new loch to be formed in Glen Orrin, five miles upstream from the Orrin Falls, by the construction of a dam 120 ft. high and 972 ft. long. The new loch will be fed from a catchment area of 54 square miles with an average rainfall of about 68 inches.

From the loch, water will be taken by a tunnel to the Orrin generating station in Strathconon near Achonokie on the southern shore of the loch to be formed by the Torr Achilty dam which is part of the Clascarnoch - Luichart - Torr Achilty hydro-electric scheme. The water discharged from the Orrin power station will therefore be set to work again in passing through the Torr Achilty turbines and a further 5,000,000 kWh of electricity per annum will be gained in this way.

The Conon Basin group will thus consist of the following schemes: Fannich, 24,000 kW (83 million kWh per annum); Glascarnoch - Luichart - Torr Achilty, 65,000 kW (280 million kWh per annum); and Orrin, 18,000 kW (79 million kWh per annum); making a total of 107,000 kW capacity and an output of 442 million kWh per annum.

A Rhône Development

Some notes are given on the work being done on the Donzere-Mondragon section of the Rhône, which involves the construction of the largest canal in Europe.

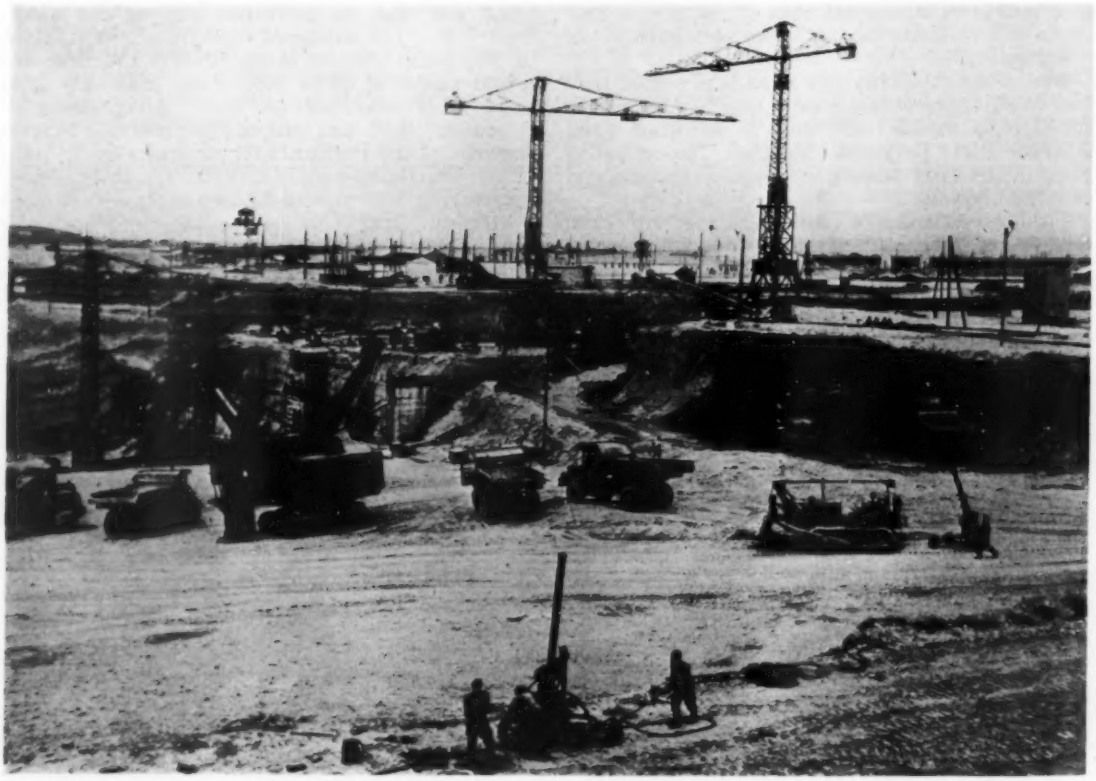
FOR the past two years twelve of the largest French civil engineering undertakings have been engaged in a major constructional feat which will be of great importance to the national economy. In this the Rhône is being diverted for a reach of 28 Km. between Donzère and Mondragon, to form a navigation way combined with a hydro-electric station capable of producing an output of 1,000 million kWh per annum. The plans were worked out many years ago but in view of the enormous expenditure in material and labour involved the project was postponed. It is estimated that 60 million cu. metres of earth will require to be excavated, requiring the services of 5,000 men for a period of five years. The two navigation locks will be the largest in Europe.

Two years were devoted to the preparatory work and a first preliminary was to provide accommodation for the 5,000 workers, many of whom have families. To meet this requirement four temporary townships have had to be built. A separate house is assigned to each family and single persons are accommodated in a building resembling a tourist home, with dormitories and social rooms. Shops, recreation halls and places of amusement have also had to be provided.

The total cost for this undertaking amounts to 730 millions in terms of Gold Francs, so that the magnitude of the work can be gauged in relation to the Suez Canal, which cost 280 millions of Gold Francs.

The economic advantages which will accrue to France as a result of this scheme will be of almost immeasurable importance. To begin with the navigation of the Rhône between Donzère and Mondragon will be greatly improved. This stretch of the river has been very unfavourable to navigation hitherto, and dredging has constantly to be employed to keep the channel open for the passage of heavy cargo barges and large tugs. These operations were very expensive and even so, in times of low water, the traffic was often brought to a standstill. The importance of the scheme to French power economy will be even greater, and it will also relieve the growing problem of water shortage. It is expected that the scheme will be completed by the autumn of 1952.

Fig. 1. Operations on the Donzere-Mondragon Canal



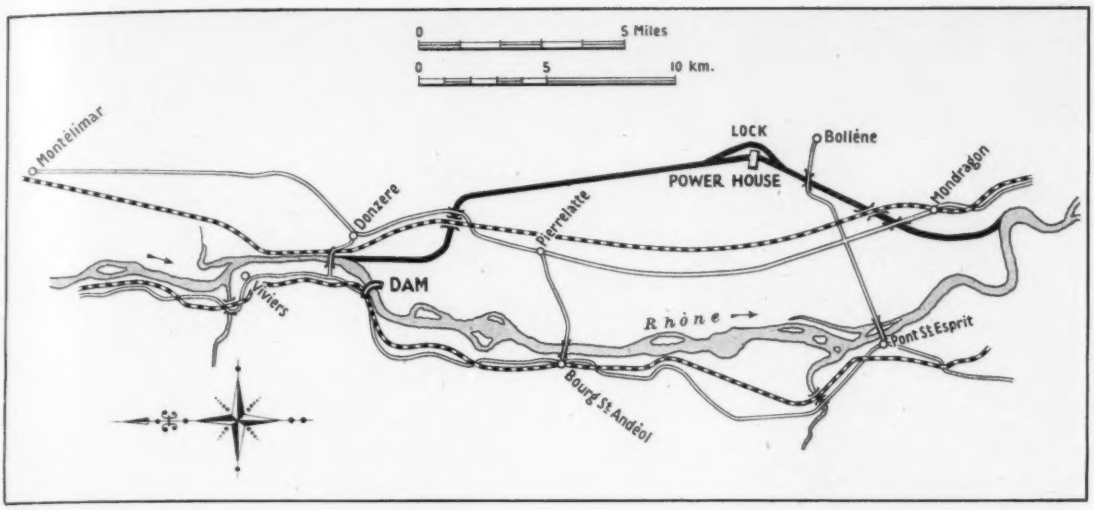


Fig. 2. Sketch map of the Rhône between Donzere and Mondragon showing canal and power house

Fig. 3. View showing foundations under construction in part of the Donzere-Mondragon scheme

Model of Cofrentes dam

Electrical Power in Spain - 1950

By M. CASTILLO, C.E. (Hidroeléctrica Española)

The present-day situation of the electrical industry in Spain is particularly interesting, many factors having contributed towards placing it in the front line of national priorities. The insufficient output of electrical power since the year 1944 has been responsible for a crisis, and has furthermore presented problems which are of concern to the entire nation

IF one looked back a little into history, it would be observed that Spain has always been alive to technical matters concerning the production and distribution of electrical power and to its outstanding transcendency. The first installations date back to 1875, and these have constantly been kept abreast of the times by adopting the latest innovations; in 1900, for instance, a transmission line was laid at 66 kV tension and extending to 225 km, which, at that time, was the most important in Europe. This elucidation seems necessary in order to judge properly over the past and present conditions of our electrical development. In fact, the consumption per inhabitant was always at a very low level, and this is to be attributed to the geographical and social conditions of the Spanish nation, whose area and population are out of all proportion to its effective wealth.

Spain is to-day faced with a population increase of 1 per cent. per annum. In contrast, the consumption of electrical power increases actually at the rate of about 5 per cent. per annum, having risen from 136 kWh per inhabitant in 1934 (24·4 million inhabitants) to 256 kWh per inhabitant in 1948 (27·7 million inhabitants). If both increases continue in similar manner it will be necessary to provide for a specific consumption of 750 kWh per inhabitant for a population of 34·5 million people by 1970.

Table I, which is largely self-explanatory, clearly illustrates what has already been achieved and, above all, the magnitude of the task which still remains to be carried out.

TABLE I

Year	Power installed MW.	Power produced 10^6 kWh.	Hours of utilisation	Proportion of hydraulic power in the total output.
1934	1,530	3,317	2,167	92 per cent.
1948	2,234	6,276	2,809	85 ,, ,,
1949	2,493	5,488*	2,201	71 ,, ,,
1970	8,000(?)	26,000(?)	3,250(?)	87 ,, ,,

*Unusual drought in Spanish rivers.

DAMS AND HYDROELECTRIC PLANTS UNDER CONSTRUCTION IN SPAIN - 1949

DAMS

No.	ALREADY IN SERVICE	RESERVOIR CAPACITY 10^6 m³
2	DOIRAS	87
4	SOMIEDO	6
6	TORINA	12
7	ORDUNTE	22
12	LAS CONCHAS	80
15	CAMPORREDONDO	70
16	REQUEJADA	50
17	CERVERA	9
18	ARLANZON	20
19	CUERDA DEL POZO	160
21	BURGOMILLODO	12
22	ESLA	1.200
23	VILLALCAMPO	56
24	AGUEDA	16
29	BURGUILLO	210
30	PUENTES VIEJAS	49
31	SANTILLANA	46
32	EL VILLAR	25
34	GASSET	22
41	CALA	60
43	LA BREÑA	115
44	LA HERRADURA	109
45	ENCINAREJO	16
46	JANDULA	342
49	TRANCO DE BEAS	500
51	TORRE DEL AGUILA	80
52	GUADALCACIN	76
53	CHORRO	80
54	PUENTES	22
55	CORCOVADO	7
56	FUENSANTA	256
57	QUIPAR	50
59	TALAVE	55
61	TIBI	4
62	ISBERT	8
65	ALARCON (H.E.)	700
68	BUSCO	8
70	SANTOLEA	54
71	PEÑA	18
72	HIJAR	4
73	GALLIPUEN	4
74	CUEVA FORADADA	34
75	MONEVA	10
79	IRABIA	14
80	ALLOZ	84
82	LA PEÑA	29
83	ARDISA	12
86	BELSUE	13
89	BARASONA	70
90	TERRADETS	33
91	CAMARASA	163
92	SAN LORENZO	10
93	ESTAGENTO	50
94	ESCALDES	5 (2)
95	TREMP	228
99	FOIX	6
56	TOTAL...	5.477

No.	UNDER CONSTRUCTION	RESERVOIR CAPACITY 10^6 m³
1	TAMBRE	35
3	SALIME	260
5	LA COHILLA	12
8	BELESAR	225
9	LOS PEARES	180
10	SAN ESTEBAN	180
11	MAO	37
13	VILLAMECA	20
14	BARRIOS DE LUNA	308
20	LINARES	58
25	SANTA TERESA	422
26	GABRIEL Y GALAN	198
27	BORBOLLON	75
28	ROSARITO	65
33	PALMACES	38
34	EL VADO	27
35	ENTREPEÑAS	800
36	BUENDIA	1.500
37	CIJARA	1.088
39	PEÑARROYA	45
40	LA MINILLA	60
42	PINTADO	175
47	RUMBLAR	126
48	GUADALEN	170
50	BERMEJALES	100
53	CHORRO	4 (1)
58	CENAJO	437
60	CAMARILLAS	39
63	BENIARRES	12
64	TOUS	25
65	ALARCON (H.E.)	400 (1)
66	LA TOBA	40
67	BENAGEBER	244
69	ULLDECONA	10
76	GONZALEZ LACASA	30
77	MANSILLA	65
78	EBRO	540
81	YESA	470
84	RESPUMOSO	30
85	BACIMAÑA	20
87	SOTONERA	190
88	MEDIANO	313
96	OLIANA	70
97	SAN PONS	25
98	SAU	117
45	TOTAL...	9.285

(1) HEIGHTENING
(2) IN ANDORRA

HYDRAULICS POWER PLANTS UNDER CONSTRUCTION.

No.		RATED OUTPUT CAPY 10^6 kWh/year
101	GRANDAS DE SALIME	320
102	ZADORRA	150
103	LOS PEARES	350
104	SAN ESTEBAN	500
105	SEQUEIROS	65
106	MONTEFURADO	92
107	NAVEA	180
108	CABIL	70
109	CASTRO	300
110	SAN JUAN-PICADAS	120
111	ENTREPEÑAS-BUENDIA	125
112	PINTADO	50
113	TRANCO DE BEAS	53
114	EL PICAZO (H.E.)	50
115	COFRENTES (H.E.)	250
116	SALLENT	50
117	LASSARRA	50
118	ARTIAS	125
119	BENOS	50
120	BARASONA	90
121	OLIANA	90
	SEVERAL SMALLER PR.	645
21	TOTAL...	3.775

Fig. 2. Dams and hydro-electric plants under construction in Spain at the end of 1949

Fig. 3. Cofrentes dam under construction

It will be seen that in the 14 years which have elapsed between 1934 and 1948 it has been possible to put into service about 700,000 kW of capacity; in 1949 a further 250,000 kW were put into service; and this rhythm will have to be maintained and even increased in the years to come if 5,500,000 kW are to be put into operation within the next 20 years.

Almost the total new capacity which in any case may be put into service will be of hydro-electric plants. In fact, the scarcity of natural fuel reduces the thermal possibilities to about 3,000 million kWh per annum, with an installed capacity of one million kW in this category, which, at the present moment, are either in service or in the course of installation. On the other hand, the potential hydro-electric power is estimated to be about 9 million kW and only 20 per cent. of it is at present exploited.

Civil engineering works for hydro-electric power generation in Spain are specially important, as they often include great dams for storing water, these latter

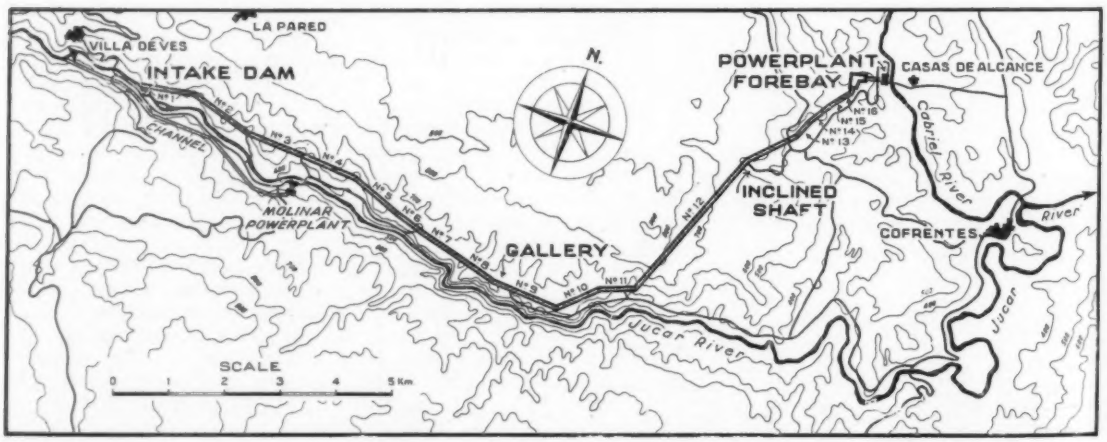


Fig. 4: General plan of Cofrentes scheme

being absolutely essential in view of the marked irregularity of the flow of most of the Spanish rivers which, in a semi-arid country, are subject to severe dry periods each year. This may be illustrated by the following example which may be taken as typical. The river Tajo, which at the point where it leaves Spanish territory and flows into Portugal, has a catchment area well over 50,000 sq. km., experienced in 1947 a peak discharge of around 15,000 cu. m. per second, causing the river level to rise by 36 m.; yet in the summer months of 1950, an exceptionally dry year, the discharge through a very long period was well under 10 cu. m. per second. The same amazing differences are encountered when comparing annual flows, which at the same location above described, amounted to something like 20,000 million cu. m. in 1936 and only about 3,000 million cu. m. in 1949.

This extreme variability of Spanish rivers is a severe economical handicap to their power exploitation, as the cost of the regulation works has a very adverse effect on the commercial side of the capacity installed.

In some cases the regulation works are undertaken by private companies in order to produce electrical power only. In others the regulation schemes are carried out by the Government with various purposes, mainly to afford irrigation facilities to dry areas. At the present time, both private companies and the Government are carrying out a programme on the grand scale as illustrated by the map reproduced in Fig. 2, which shows all the main dams, including those already built and those under construction in Spain.

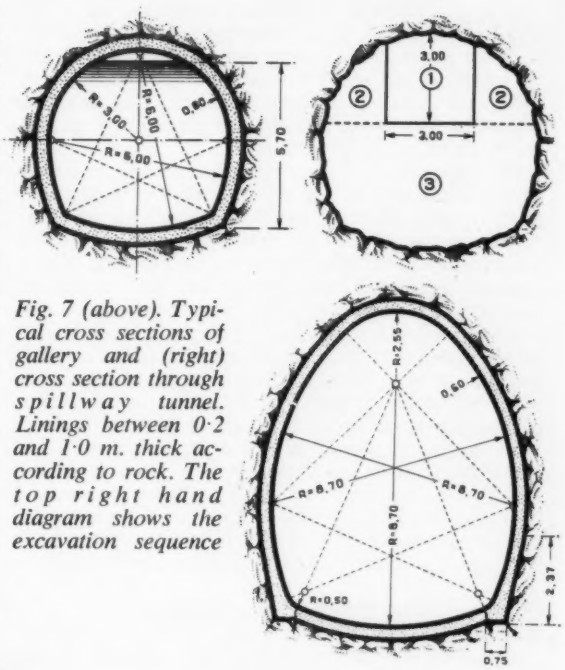


Fig. 7 (above). Typical cross sections of gallery and (right) cross section through spillway tunnel. Linings between 0·2 and 1·0 m. thick according to rock. The top right hand diagram shows the excavation sequence

Fig. 5. Power house in course of construction

From this it will be gathered that there are 56 reservoirs in service—a few more of lesser importance do not appear in the map—most of them built during the present century. A further 43 new dams are being built and two existing ones are being increased in height. The work involved by this new programme should not be under-estimated, as it includes projects such as Entrepeñas-Buendía with the largest reservoir in Europe; the beautiful arched dam of La Cohilla, 100 m. high, and many others with notable characteristics.

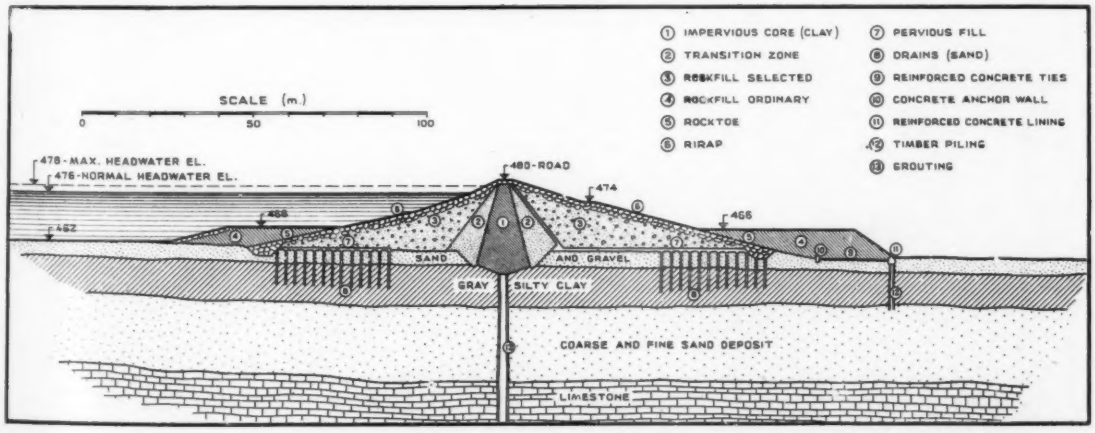


Fig. 6. Sectional elevation of diversion dam on the Jucar river

It is not possible to estimate when all this work will be completed. The programme, in my opinion, is really beyond the saving capacity of the country for a normal, say, rapid completion. Moreover, serious difficulties have been experienced in recent years in regard to importing suitable machinery against the purchase of goods from Spain.

In any event, it is clear that the erection of plants having a capacity of about 5,500,000 kW in the next twenty years will involve a serious financial problem. At the present time, cost works out at about 4,500 pesetas per kW, this including high-tension transmission lines and transformer substations at the distribution points. The figure includes 45 dollars per kW for electrical equipment which necessarily has to be imported. It follows, therefore, that the investment involved within the country should be of the order of 25,000 million pesetas and the utilisation of foreign currency amounting to about 250 million dollars.

In passing, it should be stated that these costs are lower than those mentioned in the "Report of the Electricity Committee" (Marshall Plan) for various countries in Europe; nationally or internationally subsidised schemes which were estimated at 8 million kW and valued at 2,000 million dollars (May, 1949).

The "Sociedad Hidroeléctrica Española"

The "Sociedad Hidroeléctrica Española" is a private company occupying an outstanding position among the electricity producers in Spain, as it is responsible for approximately one-seventh of the total output of electrical power in this country.

Created as early as 1907, it began operations in 1910 with the Molinar power plant. The company owns six hydro-electric power plants on the Jucar and Cabriel rivers and a coal-burning station in Madrid. Table II gives some of the characteristics of these plants, and the output in 1948, a year commonly accepted as hydraulically "normal."

TABLE II

Power Station	Inaugurated in :	Height m.	Present machinery kW.	Output 1948 10^6 kWh.	Utilisation in 1948. Hours.
Molinar ..	1910	65	18,000	96	5,333
Villora ..	1914	111	40,000	77	1,925
Cortes ..	1922	80	30,000	216	7,000
Tranco del Lobo	1925	125	2,500	15	6,000
Batanejo ..	1926	71	2,000	7	3,500
Millares ..	1934	141	80,000	406	5,075
Madrid ..	1910	(Thermal)	12,000	13	1,083
			184,500	824	4,466

Figs. 4 and 8 show the plan and river profiles for these installations, and two photographs are included of the power plant at Millares, the most important of the group, with four units of 20,000 kW each.

The company further operates 1,068 km. of high-tension transmission lines (138 kV and 66 kV) with the associated sub-stations at the boundaries of the consumption centres. It maintains interconnections with six other production groups, these linkages having been partially responsible for the excellent results obtained in 1948 in regard to utilisation of the capacity installed, and especially in the matter of meeting "peak" demand and providing emergency reserves.

The future of the company is well ensured, I think, and at the present moment two new power plants are under construction — Cofrentes and El Picazo — in addition to the reservoir already finished at Alarcón. All these activities are concentrated on the river Júcar.

The company aims to install a further one million kW on the rivers Júcar, Cabriel and Tajo. With these schemes in hand there can be every confidence that the "Hidroeléctrica Española" will maintain its leading position as a producer of electrical power in Spain.

The Cofrentes Power Plant

This is the most important scheme being carried out at present by the Sociedad Hidroeléctrica Española, the main characteristics of which are set out in the following paragraphs.

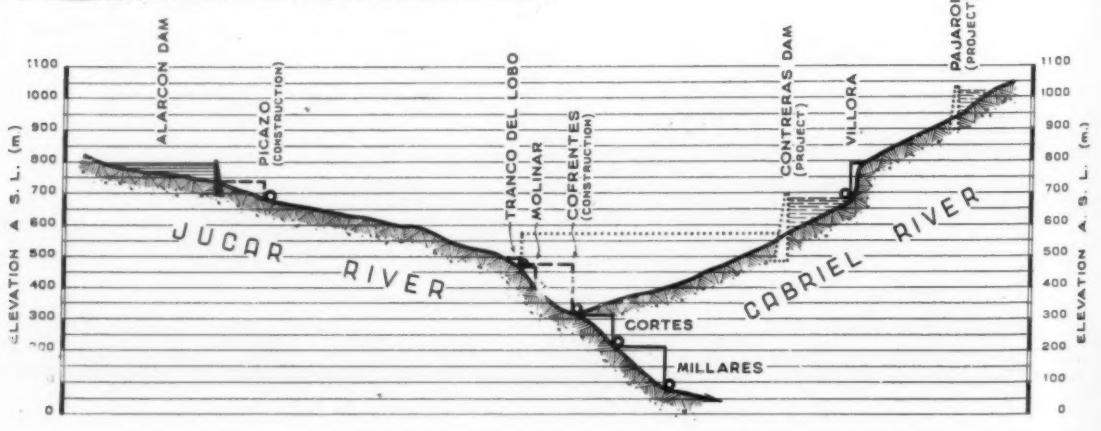
The river. It utilises a head of 154 metres on the river Júcar, out of which 14 metres are lost in frictional and other losses, leaving an effective head of 140 metres.

At the intake point, the Júcar basin has an area of 10,640 sq. km. out of which 2,900 sq. km. are regulated by the Alarcón reservoir. This catchment may receive in the future an increase of another 3,475 sq. km. by diverting water from the river Cabriel into the river Júcar through a tunnel now under consideration.

The Cofrentes scheme is a classical one (Fig. 9) and consists essentially of a diversion dam, canal, forebay, penstocks and plant.

Diversion dam. The diversion dam is of great

Fig. 8. Profiles of the Jucar and Cabriel rivers showing the power plants of the Hidroelectrica Española S.A.



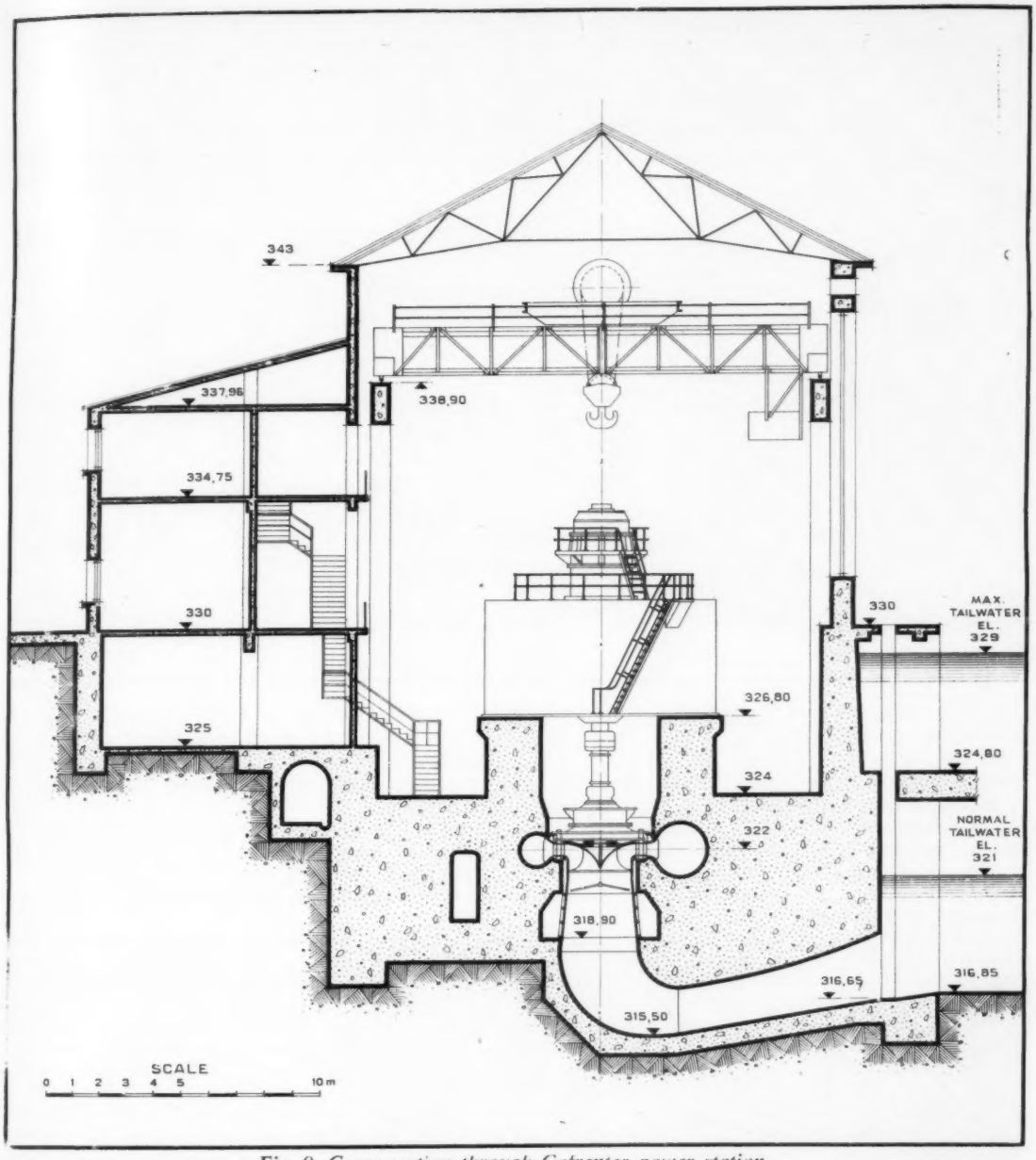


Fig. 9. Cross section through Cofrentes power station

technical interest. It is constructed of rock and clay, being the first of its kind to be built in Spain.

In fact, the country being extremely rocky, it is usual to find good foundations for all types of constructional work, and as the supply and transport of cement generally constitute no major difficulties, concrete dams have almost invariably been used.

Unfortunately in our case, what Vitrubio—the great Roman engineer—termed " terra firma " was only to be found at great depths and it would have been uneconomical to establish foundations over the calcareous rocks at a depth of 50 m. In earlier geological times very permeable sand layers have been left over the chalky rock which has a depth of 37 m.; over this there is an impermeable layer consisting of 9 m. of plastic clayey lime and at the surface there are relatively recent layers of sand and gravel having a depth of 4 m. The problem was, therefore, to lay an absolutely waterproof foundation on top of the clay without disturbing it, and limiting the pressure with regard to its plasticity.

Desired maximum pressures are 0·5 kg. per sq. cm. shearing effect and 5 kg. per sq. cm. compression; local settlement may attain 1·5 m. These considerations have led to the choice of the cross-section shown in Fig. 6. Maximum height is 27 m. and the total

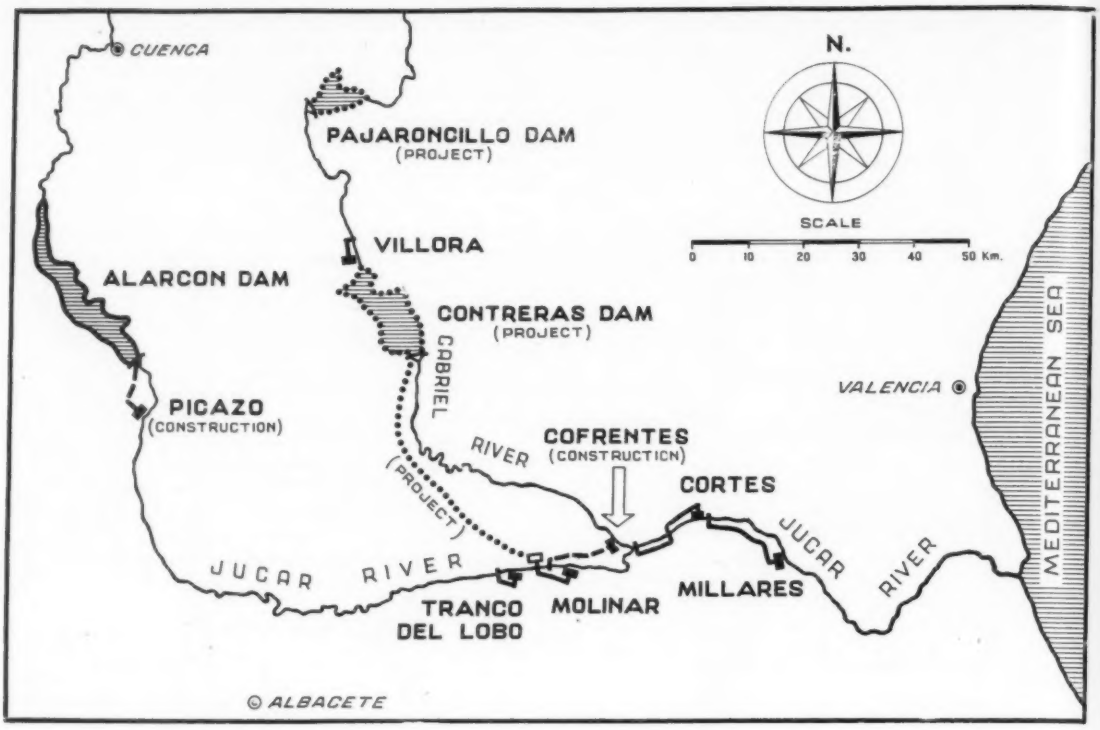


Fig. 10. Power plant system of Hidroelectrica Española S.A. present and projected

volume 200,000 cu. m. Slopes of the sides average 1 in 3·5. Noteworthy features are the screen formed by grouting below the core of the clay so as to "tie" it with the calcareous rock, the vertical sand drains on the downstream side, and the protection of the main structure from erosion by the water discharged from the spillway tunnels.

The normal maximum level of the water in the reservoir created by this diversion dam will be 476·00 metres above sea level leaving a margin of 2·00 m. for discharge purposes in case of floods and an additional safety margin of 2·00 m. to meet emergencies. Thus the crest of the dam is at 480·00 metres above sea level. The 11·20 m. storage head comprised between the datum lines of 476·00 and 464·80 (entrance to the canal) represent 11 million cu. m. of storage capacity, of which 5 million cu. m. are very useful for daily and weekly regulation.

Spillway tunnel. An arrangement to evacuate flood waters is being constructed on the left bank, consisting of two tunnels of oval cross section 11·25 m. by 8·70 m. axes. The estimated capacity is 2,000 cu. m. per sec. which should represent a high margin of safety. In fact, during the last 40 years the maximum flood flow observed was of only 1,500 cu. m. per sec., despite the fact that the Alarcón reservoir (1,100 million cu. m. storage capacity) did not then exist. Normally the spillway is kept closed by two Stoney sluice gates measuring 12·00 m. by 13·00 m. and by a third for drainage purposes measuring 12·00 m. by 5·00 m. The effectiveness of the design was tested by scale models, a number of which were constructed until that shown in the titleblock was adopted as being the most appropriate. The structure is now nearly completed.

Canal. The intake of the canal offers no points of special interest. It is situated at the entrance of the pool created by the diversion dam and is controlled by two Stoney sluice gates measuring 11·50 m. by 5·00 m.

The canal itself consists of a gallery driven along the left bank of the Júcar river having a length of 15·5 km. and a uniform gradient of 0·5 per 1,000. It has an effective cross section of 30 sq. m. and a discharge capacity of 60·00 cu. m. per second; it has an unreinforced concrete lining of varying thickness ranging between 0·20 m. to 1·00 m. according to the nature of the ground traversed.

As far as the constructional work is concerned, this canal represents the most important part of the scheme and called for the excavation of 592,000 cu. m. of rock and the laying of 132,500 cu. m. of concrete. The rock traversed varies greatly, with white chalky Cretaceous formations and the red clayey Miocene types predominating. Fortunately it has been possible to avoid the gypsum regions in the route followed.

The excavation was subdivided into 16 separate sections by intermediate openings at floor level. The longest, No. 12, was 4,125 m. long, which represented the limit of the excavation equipment we had to draw upon. The method adopted is illustrated in Fig. 7 and includes: (1) the pilot drift at the top of the gallery, having dimensions 3·00 m. by 3·50 m.; (2) the widening of the pilot drift at both sides to the definite cross section of the gallery; (3) the concreting of the top lining (archway); (4) the excavation of the bench

Fig. 11. View of Alarcon dam and reservoir under construction

until completion of the cross section; and finally (5) concreting of the rest of the lining. The mechanical equipment used was kept down to a minimum as it was necessary to overcome many difficulties in supply. This work is practically finished.

Forebay. The forebay has a total capacity of 110,000 cu. m. storage water and is scarcely worthy of mention from a constructional point of view; it involved the excavation of 82,300 cu. m. of rock to secure the above mentioned useful capacity of water and its maximum depth is 20·40 m. near the inlets of the penstocks.

Penstocks. Penstocks will be of steel, ranging in diameter from 3·00 m. to 2·80 m. and having a length of 450·00 m. each of three conduits. The individual sections are 6·00 m. long and have welded joints.

Power plant. The power station, a cross section of which is reproduced in Fig. 9, contains three generating units of 40,000 kVA each so that the total installed capacity will be 120,000 kVA, corresponding to 108,000 kW with a calculated power factor of 0·9 for the outgoing lines.

In its construction some 35,800 cu. m. of clay had to be excavated and 12,600 cu. m. of concrete were required, of which 500 cu. m. were strongly reinforced. The roof is made of steel trusses. The construction work for the power plant is nearly completed and actually we are proceeding with the erection of the first unit.

Fig. 12. General view, Millares plant

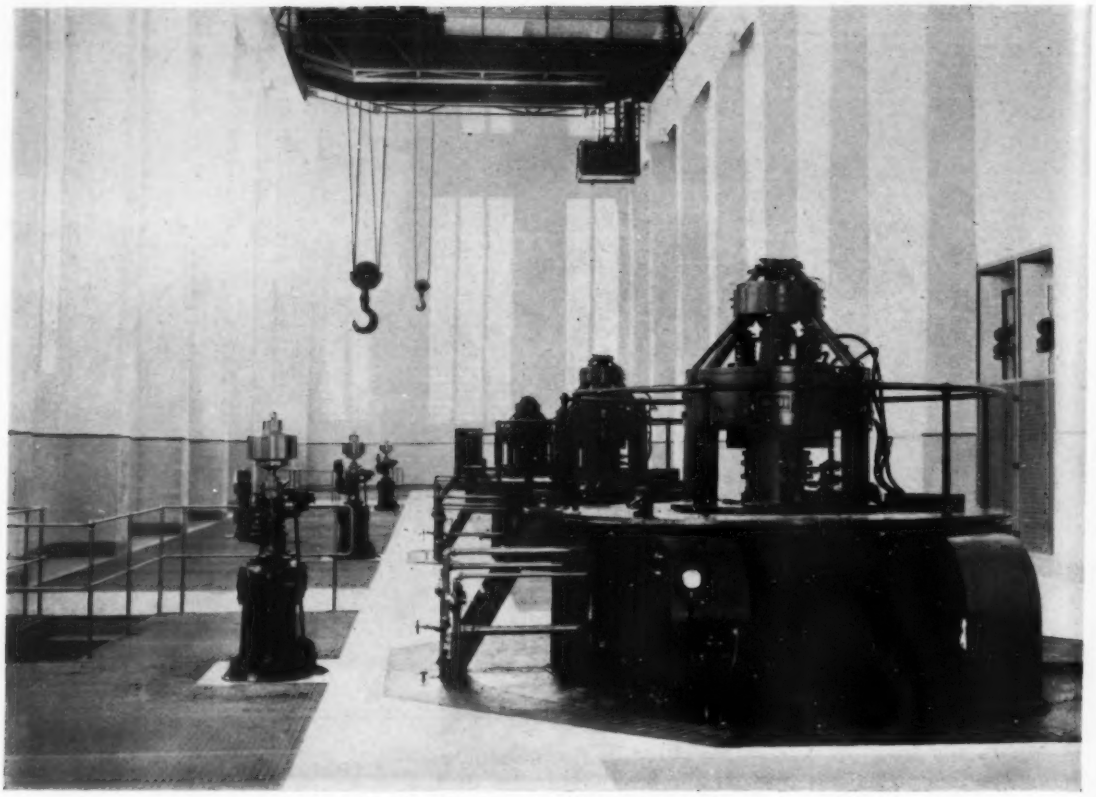


Fig. 13. Interior of Millares power house

The transformer bank and the outgoing switchgear are being erected nearby.

Energy output. It is estimated that the energy output will be of 250 million kWh per annum during the first stage, that is, utilising the waters from the river Júcar alone; it may, however, increase at the rate of 375 million kWh per annum in the event of the canal connecting the river Cabriel being constructed.

It should be noted from the accompanying map (Fig. 10) that the Cofrentes scheme will make the Molinar power plant redundant. This power station was put into service in 1910 and had an average output of 80 million kWh in recent years. Thus the Cofrentes power plant will add only 170 million kWh to our system.

Of course, the machinery in Molinar is very antiquated. Moreover, as the possibility of the river Júcar carrying sufficient water for the operation of both stations is extremely remote, once Cofrentes is in service, the dismantling of Molinar will be proceeded with.

Conclusion. The whole task has involved a total of 1,220,000 cu. m. of rock removal and the placing of some 285,000 cu. m. of concreting of all types. Planning was started in 1944 and the work itself was begun in 1946. It is hoped that by the third quarter of 1951 the first unit will be in operation. Constructional work is actually 70 per cent. completed. In fact, it was pointless to proceed faster with the civil engineering work as we were dependant on the terms offered by the manufacturers of the electrical equipment, who were granted the contract late in 1946.

The contracts for the machinery were granted entirely to British firms: the turbines and electrical machinery to the English Electric Co. Ltd; the penstocks to South Durham Steel & Iron Co. Ltd.; the sluice gates to Ransomes & Rapier Ltd.; and the main travelling crane (175 tons) to Sir William Arrol & Co. Ltd.

Hydro-Electric Generators

Bruce Peebles & Co. Ltd., Edinburgh, have just published a handsome booklet on hydro-electric generators. This firm has been active in the hydro-electric field since 1903, and reference is made to the Snowdon scheme which was completed in 1906. Brief details are also given of the Morar and Lochalsh installations, representing the first schemes of the North of Scotland Hydro-Electric Board. Much of the booklet is devoted to notes on construction of both horizontal and vertical types, including ancillary equipment such as the braking and jacking system, overspeed device, heaters, bearing thermostats, temperature indicators and fire prevention. An important section describes some typical machines, including the 13,333 kVA sets recently supplied to Grudie Bridge. A brief section is included on synchronous condensers, and a list of representative users, both in Great Britain and throughout the world, is given. The booklet is excellently printed and lavishly illustrated.

The Fourth Congress on High Dams

In our last issue we gave a brief account of the four engineering conferences held in New Delhi, India, in the early part of year. The section likely to be of most interest to hydro-electric engineers was that devoted to High Dams, and we give a detailed summary of the papers and discussions.

FLOOD DISCHARGE AND SPILLWAYS

THIS was the largest section in regard to the number of reports, as forty-two were submitted, and in the discussion that followed twenty-two speakers took part.

The first part of this subject—methods for determining maximum flood discharge—showed that three approaches had been made. The first was formulæ of probability, the second empirical formulæ, and the third the use of observed data.

Seven Papers gave suggested formulæ for flood discharge, which were all based on different methods. Different authorities were quoted, but their conclusions often conflicted, and the various formulæ put forward were all fundamentally different in character.

In the second section, where empirical formulæ were dealt with, the methods were to derive graphs and formulæ from observed records of great floods and endeavour to calculate other formulæ and curves which will fit the records, although most of them were not based on mathematical lines.

The third method—the use of observed data—simply meant that where reasonably long-term run-off records are available, evaluation of the probability and size of future floods can be more or less reliably made; although more than one author suggested that complexities of climate may mean the prediction of floods can never be more than inspired guess work. The Italian Hydrographic Service, as indicated in a Paper by Piccoli, has evaluated flood discharges from the study of intense rainfall for short durations. Curves of the form $h = a\,T^n$, where h is the highest value of rainfall for a given time T, have been plotted, and show that maximum rainfall varies from region to region, and in the same region from basin to basin.

Modulation of Floods

The second main subject in this part of the Conference related to the modulation of floods through reservoirs. Here it was stated by three French authors that the problem of designing a flood drain capable of dealing with the whims of the river is not yet solved. A compromise between the type of flood and that of the flood drain may not be suitable for maximum flood flows, or (in regard to the heavy costs of such works) to the economics of the scheme as a whole. The catastrophic flood governs the design of overflow works. A factor q was evolved, as the ratio of flows under the maximum and normal flood conditions. For floods where the maximum rate of flow lasts for a considerable period, flood discharge works may be designed with q having an approximate value of 1, but for sudden and violent floods this might not be technically correct. The flood modulation effect and the storage capacity of the reservoir may be adjusted to provide an economic and scientifically correct solution to this problem; but this coefficient q determines the economic considerations. The lesser the value of the ratio q, the less extensive the project. The ratio q is a function of the geological configuration, the topography, the rainfall and run-off, and the mechanical quality of the soil of the flood drain.

Spillways

In the third section, dealing with spillways for high dams, it was shown that in India a considerable amount of work is in hand at hydraulic research stations, chiefly based on model tests and prototype spillways. The ski-jump type of spillway is used largely in France, an example being the Chastang Dam, where two such spillways are arranged as part of the roof of the powerhouse. There are additional discharge arrangements through two temporary discharge galleries.

The volute siphon spillway is a relatively new design for large-scale application. It consists essentially of a dome with a funnel placed underneath, leaving an annular space all round, with a vertical pipe taken down the funnel to pass the discharge out through the dam. The lip of the funnel is at the full reservoir level, and a number of volutes, like the blades of a centrifugal pump or a turbine, are so placed as to induce a spiral motion to the water. When the water in the reservoir rises above full reservoir level, it spills over the circumference of the lip of the funnel, skirts along the volutes, and at the throat falls into the barrel forming a water seal turning with a spiral motion. The air in the siphon trapped between the inlet and the water seal is evacuated by various processes; viz., dragging in air at the surface of the water flowing along the funnel; screwing out air due to the spiral motion given to the water; air dragged by the spray of water formed by the turbulence; physically trapping the air in pockets formed by the different angle of the throw-off of filaments at the throat.

As the water overflows the lip of the funnel, it enters the space between the volutes and flows radially along the slope of the funnel, heaping up along the outer side of the volute. While continuing to flow in the same direction, a portion of the flow is pulled down the slope of the funnel and spreads out fanwise. These fan-like layers of water in the spaces between the volutes are thrown out into the

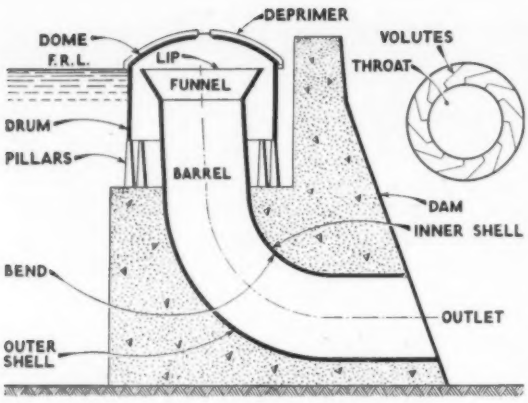


Diagram showing construction and operation of volute syphon spillway

barrel. Due to the different radial and circumferential components of the velocities induced in the filaments, the fan-like flow is not in one horizontal plane but is tilted, and air is trapped between the layers.

As the air is dragged down in all the four ways mentioned above, the pressure above the water-seal portion begins to fall. As the depth of the drum is generally kept high, there is no possibility of air getting in from the reservoir side to make up for the fall in pressure. The air, therefore, enters from behind the outlet and rushes to the dome to make up the fall in pressure as long as the water seal is too thin to resist its being punctured through. When the air is thus trying to enter from behind, there is a rise in the boil point. If it gets punctured it falls through again. There is thus for a time a pulsation of flow, the boil in the barrel moving up and down. As soon as a sufficiently strong water seal is established with the necessary rise in reservoir level this up and down movement ceases, and the strength of the vacuum begins to increase steadily. Since at this stage air can no longer enter from behind, more water from the reservoir side is pushed in due to the increasing difference of atmospheric pressure. As more water enters, the sucking action becomes more powerful, resulting in a further entry of water which in turn creates a greater vacuum. This chain reaction develops rapidly and in a few moments the siphon runs full. To start the reaction, a difference in pressure equal only to 1½ ft. head of water between the inside and outside of the water seal is sufficient. In the Hirebhasgar siphons, which are probably the largest in the world, and which have a dome 38 ft. in diameter, siphonic action started within ten minutes of the commencement of its priming. During depriming, the reverse action takes place when air begins to enter through the deprimers.

A Paper by MM. Delattre and Henry of France, gave some interesting details about the spillways at Genissiat. The surface spillway on the right bank discharges during several months at a rate of between 3,530 and 10,600 cu. ft. per second, the water being returned to the river far enough downstream to prevent the spray from causing any damage to the power plant. The channel is 1,640 ft. long, and can discharge up to 88,300 cu. ft. per second. It terminates in a raceway, the extremity of which guides the water back into the Rhone river by means of a "hydraulic jump" discharge. It is especially interesting to note that a deep excavation has been formed in the river bed by the force of the discharging water without, however, forming a sandbar at this downstream point.

The left bank spillway has a pressure outlet 150 ft. below water level, and as the river transports a very great deal of silt which is deposited into the reservoir, the geographic location of the underground spillway afford a means of flushing out the silt.

Stilling Pools

The next part in this section dealt with stilling basins. A Paper by Messrs. T. P. Kuttiammu and J. Visweswara Rao of India, described the basin at the toe of the Bhavani dam spillway, which consists of a depressed apron provided with T-shaped floor blocks. The authors stated that it had been devised and perfected by a large number of systematic experiments on hydraulic models, and that it was suitable for adaptation to large dams. Its special features are that a standing wave is ensured inside the basin for all conditions of flow; second, the destruction of energy inside the jump is fairly complete, as indicated by the absence of any hump in the standing wave profile; third, the floor blocks are strong and stable in design and free from cavitation; and finally, the entire design is extremely economic on account of the short length of apron provided. The whole principle is based on the fact that the most efficient, and generally the most economic way of affecting the transition from the very critical flow to the supercritical at the toe of a spillway dam, consists in ensuring the formation of a standing wave just below the toe for all conditions of flow. With a well-formed standing wave the surplus energy in the supercritical stream gets dissipated by conversion into turbulent energy and heat, and the high velocity jets get deflected to the top of the stream and their speed retarded at the maximum rate. If the dissipation be fairly complete the standing wave will have no hump or boil, and consequently the erosion of the river-bed below will be effectively prevented.

The lower Bhavani dam has a height of 180 ft., an overflow depth of 15ft., and a tail water depth of 33 ft. The stilling basin is 33 ft. long beyond the toe of the bucket, and 10 ft. deep. A single row of rectangular blocks 8 ft. × 4ft. × 6ft. and spaced 16 ft. apart, is located on the stilling basin floor at a distance of 6 ft. downstream of the bucket toe. Each of these blocks is buttressed against the end wall of the basin by a long wall 4 ft. wide and 5 ft. deep. This design was found to yield an extremely efficient standing wave, without any hump on its surface, for the full range of fluctuations in the flow conditions. Being under full submergence, the floor blocks are free from cavitation. The authors suggest that this design could be adopted for spillways of large dams and for small weirs as well.

Stream Diversion Problems

The final part of this section of the Conference dealt with problems of stream diversion. The Paper by Mr. William McAlpine of the United States, dealt with diversion problems encountered during the construction of some six dams, and showed that no two sites were alike. One diversion was of particular in-

terest and concerned the Blakely Mountains Dam on the Ouachita river, about 10 miles north-west of Hot Springs, Arkansas. The economy of an earth dam was considered to outweigh the advantages of a gravity dam in overcoming diversion hazards. The river is subject to sudden floods which may reach 30 or 40 ft. above low water level. The restricted space afforded by the gorge-like site is better adapted to concrete construction to meet problems of diversion than an earth dam, but after a careful study of the comparative advantages, particularly of the costs, and the evaluation of the very considerable risks involved, the decision was made to construct an earth dam. This decision is of particular interest to those engineers who have to construct dams in very narrow valleys.

EARTH AND ROCK-FILL DAMS

In this section twenty-three papers were presented, and considerable information was given on present day practice, and the study tour, which took place after the Conference, gave delegates an opportunity to see examples of earth-filled dams now being constructed in India.

Dealing first with earth dams, Messrs. V. M. Jevdjevic and B. M. Rajcevic gave a short history of large dams in Yugoslavia, describing the local conditions governing the choice of type. An account of ancient earth dams built in India, some as old as 1600 years and still in service, was presented in a Paper by Mr. K. L. Rao. More than 20,000 of such dams are located in Madras State alone. The main cause of failure was the inadequate spillways. He gave an interesting specification for a dam dating back 600 years.

Suitability of the Site

In a Paper by Mr. P. T. Bennett of the United States, attention was drawn to the fact that the cost of the embankment portion of an earth dam may be a relatively small part of the total cost, and that the suitability of the site depends as much, if not more, on its adaptability for a spillway or other major structure rather than the embankment itself.

In the part of this section relating to the design of earth dams, many Papers recommended the exclusive use of the Swedish slip-circle method for the analysis of the stability of fills. Messrs. W. W. Daehn and J. W. Hilf, of the United States, described that method in detail, and together with Messrs. C. E. Blee and R. M. Riegel, also of the United States, recommended a factor of safety of 1·5. It will be noted that this recommendation must have been for a given type of material, as it ignores any variation in materials and the relative reliability of tests and methods applicable thereto.

Recommendation was made by Mr. P. T. Bennett of America, of the use of both the slip-circle and also another type of analysis which consists of estimating unit stress conditions in critical regions. He also recognised defects in both methods and recommended that results from them be given equal weight.

In a paper by Mr. Frohlich of Austria, a formula was given which indicated the factor of safety with respect to the sliding of the upstream slope of earth dams on an assumed slip circle, when subjected to partial or complete drawdown. He applied his formula to a French dam failure with a satisfactory agreement.

Mr. K. L. Rao of India, in his Paper, considered that, in determining the stress or stability of earth dams, no appreciable progress is recorded since early times, and that the advances made in such structures are mainly in construction practice and not due to any established design refinements.

An empirical formula was given by Mr. P. T. Bennett of America, for making an initial estimate of the slopes of earth dams before beginning the long process of trial-and-error design. He called attention to Kellogg's demonstration that tight, impervious clay, which yields practically no water by gravity, drains during sudden drawdown at rates comparable to those associated with porous materials, and he believed that the most critical materials are very fine sands, silts and poorly compacted clays, all of which have a high ratio of water content to permeability. Therefore he recommended the proper use of tight, impervious clays for the upstream slope.

Monsieur Frontard, of France, explained earth slidings in connection with the upstream slope of six French dams. Each slide occurred when the central part of the dam exceeded what he calls the "dangerous height," for which he gave an equation, while Monsieur Rumilly, also of France, described an earth 71·5 feet high, with a 2 on 3 downstream slope, and a 2 on 3 and 1 on 2 upstream slope. Leaks and saturation occurred. The lower half of the downstream slope was flattened and clay grouting and cement grouting was done which reduced the leaks and stabilised them.

A method for estimating the net flow corresponding to the sudden drawdown case, was presented by Messrs. Daehn and Hilf (U.S.A.). The authors also showed that excessive pore pressures are frequently created in the impervious zones of earth dams due to the pressure of superimposed earth loads within the mass, with insufficient time for complete drainage. These pore pressures may create the most critical condition of design, but the rapid drawdown state and the steady state with full reservoir, should also be investigated.

It was stated that these excessive pressures can be eliminated by using a compaction moisture content of from 1 to 3 per cent. less than the laboratory optimum. The authors also indicated that the amount of such pore pressures can be estimated by triaxial tests or by calculations based on the results of the less expensive drained compression tests.

Triaxial tests of this type were dealt with in a Paper by Mr. F. M. Lee of Australia, in which he stated that tests on samples at 2 per cent. above the optimum water content developed about 90 and 160 lb. per sq. in. pore pressures at 100 and 200 lb. per sq. in. applied total stress, respectively; while samples at 2 per cent. below optimum developed only about 8 and 20 lb. per sq. in. at 100 and 200 lb. per sq. in. pressure.

Mr. B. Lofquist of Sweden, gave a method for determining the earth pressures in thin, vertical impervious cores, and gave results of actual measurements of such pressures. These pressures are said to be indicative of the forces tending to cause failure of the dam.

British practice in regard to the design and construction of earth dams was given in a paper by Messrs. E. C. Steer and G. M. Vinnie.

It was considered by Messrs. V. M. Jevdjevic and

B. M. Rajcevic (Yugoslavia), that each small volume in an earth dam must be compacted to a density corresponding to the density to which the superimposed load will consolidate it.

Rock-fill Dams

Mr. L. F. Harza (U.S.A.) divided rock-fill dams into four general types, characterised by the location of the impervious element.

(a) Monolithic thin concrete diaphragm on upstream face.
(b) Central thin vertical core, usually of earth.
(c) Central thick vertical earth core.
(d) Thin impervious core dipping upstream.

Mr. Harza, together with Messrs. C. E. Blee and R. M. Riegel, also of America, then described methods of constructing and outlined the relative advantages of each type. Type (a) results in the least volume, but the concrete diaphragm frequently cracks due to settlement of the rock fill. He stated that in North Africa, flexible types of upstream diaphragms, using plastic material to prevent cracks, are being tried out. All three authors did not consider this type to be applicable where the reservoir cannot be completely drained at intervals for inspection and repairs.

Monsieur G. Pahud of Belgium described a tight rock-fill dam at which the upstream concrete facing is composed of reinforced concrete slabs with copper seals and asphalt fillers and a special hinged joint at the bottom. Mention was made by Mr. Harza of one dam in which a steel-plate upstream facing was used but as yet no reports on its effectiveness have been made; he also referred to another in which a steel central core was used, but was soon destroyed by overtapping.

An earth-core type of rock-fill dam was favoured by Messrs. Harza, Blee and Riegel, and they described that first used at Nantahala, North Carolina, in which the thin impervious earth core and its filter layers dip upstream at such an angle that the main portion or supporting rock fill, downstream from it, can be built as an independent operation with both slopes on their angle of repose and hence in high lifts. It is considered a cheaper type than that having a thin vertical central earth core.

Mr. Harza condemned the use of thin concrete cores in rock-fill dams due to their tendency to crack under unequal loading, while Messrs. Blee and Riegel stated that the practice of the Tennessee Valley Authority is to use from 1·4 to 1·7 times as much sluicing water as volume of rock fill, remarking that some American engineers advocated the use of much greater quantities. Messrs. G. Westerberg, G. Pira, and J. Hagrup of Sweden, mentioned the use of twice as much water as rock fill.

The use of the slip-circle method for computing the stability of rock-fill dams with earth cores, was advocated by all three of the American authors.

A description of a full-scale shearing test on a rock fill composed of high-grade sandstone, in which an angle of internal friction of 45 deg. was adopted in the design, was given by Messrs. Blee and Riegel. They also stated that the foundation for a rock-fill dam must generally be rock, but Messrs. Raicevic and Jevdjevic (Yugoslavia) mentioned a rock-fill dam built on a thin layer of alluvial deposit.

In the discussion, some speakers favoured the use of a clay core in preference to concrete, on account of the difficulty of the construction joints. A composite core wall design is in use in Sweden, where a thin reinforced diaphragm wall is arranged with a clay or impervious earth layer on the upstream side. Other speakers dealt with the use of clay core for the main section, with a concrete or masonry under structure below the clay walls. A concrete underwall is particularly effective where it may be necessary to grout the under foundations of the dam against seepage.

The point which arose from the discussion on rock-fill dams, was the importance of proper consolidation of the rock-fill. Swedish engineers advocated water sluices as being the most effective method, and the use of vibrators for the consolidation of the rock-fill was also advocated.

SILTING AND RELATED PROBLEMS

The silting of reservoirs has become a serious problem in connection not only with hydro-electric schemes, but also with irrigation projects. Sixteen papers were presented, including one from Great Britain, by Sir Cyril S. Fox.

The Papers showed that erosion and the transport of its products depend on many natural factors, such as the size of the catchment, its topography and geology, and particularly its lithology and climate. Each author gave his own experience in relation to the areas in which he had carried out work.

Sir Cyril Fox began by giving some interesting statistics which showed, amongst other details, that for a large river such as the Mississippi, which drains 1,265,000 square miles and has an estimated annual discharge into the Gulf of Mexico of 19,500,000 million cu. ft., the quantity of dissolved matter is about 0·15 lb. per 100 cu. ft. The amount of suspended matter in the river amounts to some 362,000,000 tons each year, which would make a heap 240 ft. high over an area of one square mile.

Material is carried along by a river not only in suspension, but also in solution. Again, there is sediment rolled along its bed, and a calculation for the Mississippi river suggests that each year some 750 million cu. ft. of sediment is conveyed in this fashion in addition to the dissolved and suspended matter. This is generally known as "bedload."

The transporting power of water is given in the accompanying table:—

THE CARRYING CAPACITY OF FRESH WATER

Material	Dia. of Particles		I.M.M. Mesh	Velocity in ft. per sec.	
	In.	mm.			
Fine Sand	0.005	0 127	100	0.25	
" "	0.007	0.180	70		
" "	0.01	0.254	50		
Medium Sand	0.0125	0.317	40	0.50	after the material is in motion.
" "	0.0166	0.421	30		
" "	0.025	0.535	20		These are not
Coarse Sand	0.0416	1.056	12	0.75	scouring velocities.
" "	0.05	1.27	10		
" "	0.062	1.57	8		
Fine Gravel	0.10	2.54	5	1.00	
Medium Gravel	0.50	12.70		1.50	
Coarse Gravel	1.00	25.40		2.50	
Shingle up to	3.00	76.2		4.0	

The scouring power of water is regarded as very nearly proportional to the square of the current

velocity, but in practice this is subject to modification by the following factors: the relative roughness and uniformity of the channel; the nature of the rock or the material exposed in the bed; and the amount of suspended abrasive material.

Other papers showed that hydraulic laboratories and research stations in all parts of the world are devoting a great deal of time to studying the problems associated with silting, and in particular thixotropy, which shows that when particles are of colloidal size, irrespective of the nature of the material, they can, when mixed with water, become a "jelly-like" liquid mud. This mud, if undisturbed, behaves as a solid, but becomes instantly fluid if shaken.

Silt excluders were dealt with, and it was mentioned that these are generally arranged at canal headworks or at a suitable point where a proportion of the river-flow can be diverted, together with the heavier bed silt. Other methods are to employ under-culverts in the line of a main stream-flow, arranged to divert the lower water layers downstream, while upper layers enter through the headworks' gates. In American practice, in regard to reservoirs, stilling ponds are employed frequently, and these have to be dredged at suitable intervals. In Algeria, control over erosion has been attempted by cultivating the lower slopes, by growing fruit trees on terraces in the mountains, afforestation and other means.

General concern was expressed, in the discussions, at the high cost of works designed either to reduce erosion and sedimentation, or to deal with its effects.

A number of matters for further study were suggested, these including methods of measuring the amount of material transported along the bed of a river and the possible differences in kinds of underflow. It was also suggested that the consolidation of alluvia should be further considered, including the part played by clayey materials.

When dealing with floods, it was thought that investigation was needed into methods of evacuating by way of large sluice ways in the bottom of the dam, in preference to using surface weirs.

The General Reporter summed up this section by stating that the phenomena which lead to the silting up of reservoirs had been fully revealed and engineers in general were badly equipped to deal with them. He continued, "There is torment in the thought that great human achievements productive of safety and wellbeing depend on works whose expectation of life is confidently estimated at less than two generations."

CONCRETE FOR HIGH DAMS

The large number of papers submitted under this heading were sub-divided into the properties of concrete, including studies of creep and extensibility and the effects of grading and air entrainment; cracking under dams; and the use of mass concrete made of puzzolana, blast-furnace slag, hydraulic lime, and other materials.

It was shown that in the case of the gravity dam, density rather than high strength is required, apart from the question of water tightness, which is common to all dams. Density is mainly a matter of cement and aggregate, while water tightness is obviously related to cracking.

The Paper by J. M. Raphael and C. Rawhouser of the Bureau of Reclamation, Colorado, U.S.A., showed that cracking is controlled to some extent by the way in which the concrete is placed. They stated that cracking is generally associated with stress caused by volume changes in the mass concrete. These volume changes are chiefly caused by temperature variation, but the expansive reaction associated with the chemical blending of the alkali and the aggregate is also an important cause of cracking. Most of the cracks occur on surface and are caused by temperature differentiations between the relatively cool atmosphere and the warm interior of the mass. Therefore, careful control of the temperature during construction will greatly reduce the tendency of cracks to form. It was shown that cracking might also be caused by differential vertical movements during construction. It may result from loss of support due to contraction of backfill material in foundation trenches, or as a consequence of a shearing movement when concrete placed near a steep abutment shrinks in downwards direction relative to the abutment. Concrete placed in shallow lifts over large areas of foundation rock, or on other concrete that has already obtained volumetric stability may develop tensile stresses as it cools; and this may also result in cracking.

The authors showed that seasonal temperature cycles cause variations in stress of up to 800 lb. per sq. in. or more on surfaces exposed to the weather. Twisting action near steep abutments can also cause structural stresses which finally result in cracks.

Other authors suggested that a method of reducing certain types of crack is by the use of "low-heat" cement instead of ordinary Portland. L. B. Nilsson of Sweden, for instance, gave some interesting data about adjacent buttresses in the Ljusne Strömmar dam, situated in central Sweden. Here the dam is divided by extension joints into thirty-five monolithic units. Two of these were the subject of special experiment, one being made with low-heat and the other with standard cement. Measuring instruments were placed in the buttresses in the same relative positions, and Mr. Nilsson showed that the maximum temperature rise observed in the concrete made from low-heat cement amounted to about 68 per cent. of the corresponding value for standard cement. The buttress made from low-heat cement—the only one in the dam—has not at any time exhibited any cracks.

Some authors suggested that cracking in a concrete dam had to be expected, and the best solution was to take other steps towards water tightness. One of these methods was to install a separate reinforced concrete diaphragm covering the upstream vanes of the dam. This method has been largely used in Scandinavia.

Brigadier G. B. Gifford Hull, of Great Britain, suggested that a return to the type of construction using large stone or pre-cast concrete blocks would result in a denser material and less liability to cracking. The author felt that if thought were devoted to the problems entailed in quarrying and handling blocks of up to 20 tons in size, an economic solution could be found. An upstream water-proof membrane would be used in addition to the stone blocks.

On the subject of creep, the Paper by C. R. Lee of the Building Research Station, Great Britain, was very informative. Mr. Lee set out a large number of testing methods, and his somewhat unusual approach to the question of testing has been to subject a fixed

and constrained specimen to variations in temperature, rather than to submit an unrestrained specimen to a constant stress.

The result of tests carried out by W. H. Glanville at the Building and Research Station, show that not only are the immediate deformations proportional to applied stress, but that the specimen creep figures over a period of at least a year are also proportional to stress, for stresses up to about one-third of the crushing strength. His results also indicate that the rates of creep per unit stress in compression and tension are substantially equal, the creeps in each case being calculated as the difference between movements of loaded and non-loaded specimens. The assumption of proportionality of creep and stress in both tension and compression much simplifies creep calculation.

Heat of Hydration

The use of puzzolana, blast furnace slag, hydraulic limes, and other similar materials in Portland cement concrete was dealt with in a number of papers. The disadvantages arising from the use of ordinary Portland cement in mass are well known, and much has been done towards the development of alternative materials which offer in particular lower heats of hydration and improved workability, together with greater freedom from cracking. A considerable number of materials are now available for this process. In India, experiments are in hand for making use of surkhi, a powdered, burnt clay, as a puzzolanic admixture to Portland cement mortar, to form the so called "red cement mortar." Admixture of surkhi up to a proportion of 25 per cent. has been accompanied with very moderate losses of concrete strength, and with reduced seating temperatures.

The entraining of air gives increased workability and has been found in the United States to be of value in the placing of lean, dry mixes. Suitable agents for air entrainment have, however, not been freely available outside the U.S.A. Mr. Lyse, of Norway, has investigated a number of such materials and one of them, tallolje (spruce oil) has been found to be both economic and to have properties similar to the standard American practice. These resins, or oils, added to the concrete mix cause very small air bubbles to be entrained in the mass. While not reducing the strength of the concrete by any material amount, and, as mentioned above, improving the workability, they also have the advantage that they reduce its cracking propensities. Again, it has been found that there is increased resistance to freezing.

A point of interest in those parts of the world where hydro-electric and thermal power stations exist in close proximity, is the possibility of using fly ash from pulverised fuel, as a puzzolanic admixture for cement. This material, the disposal of which causes very considerable problems in many cases, is inert, and experiments are in hand to discover whether its incorporation in concrete mixes would have advantages in regard to the reduction of temperature.

North of Scotland Schemes

THE North of Scotland Hydro-Electric Board have published particulars of their Breadalbane scheme (No. 25) which it is estimated will produce an average output of 304 million kWh per annum, by using the water resources of some 186 sq. miles of Perthshire. It will consist of three sections (Killin, Luib and St. Fillans) and is estimated to cost over £15,000,000. It provides for the use of the head waters and tributaries of the Rivers Lyon, Lochay, Dochart, Lednock and Almond, the Monachyle Burn and Loch Earn.

The Lawers Scheme (No. 18) already approved by Parliament, which has a capacity of 30,000 kilowatts and an average estimated output of 71—80 million kWh per annum, will be linked to and controlled along with the Breadalbane Scheme from a centre at Killin. The eight stations of the group will have a total capacity of 118,500 kW and an average estimated output of 384 million kWh per annum.

The works to be constructed in the Killin section of the scheme include three dams and three generating stations. Two of the dams are to be in Glen Lyon. The larger situated near Lubreoch will augment Loch Lyon into which additional water will be brought by aqueduct across the divide from Glen Lochay. Lubreoch generating station will be built into this dam and will discharge water to a second dam near Stronuich. This dam will form a much smaller loch and on the north shore the Giorra station will be situated while on the south shore there will be a tunnel leading to Glen Lochay.

Further substantial storage is to be obtained for the scheme by the construction of a dam across the Allt Conait to enlarge and unite Lochs Daimh and Giorra. The water from this combined loch will also be fed into the storage at Stronuich, by way of a tunnel, to the Giorra power station.

The water from the small loch at Stronuich will pass through the tunnel to the Lochay power station in Glen Lochay near Murlaganmore. This station, which will have a capacity of 50,000 kW will discharge into the River Lochay. Additional water from certain of the head streams of the Rivers Dochart and Lochay will be collected by aqueduct and diverted into the pipeline which supplies the Lochay generating station.

The Luib section of this scheme consists of collecting aqueducts and a small dam across the Monachyle Burn in the hills to the south of Luib. From this small loch, water will be led by tunnel and pipeline to Luib generating station 965 ft. below on the River Dochart to the west of the railway station.

The St. Fillans section of the scheme will involve the construction of a dam at the outlet of Lochan Breachlaich and the water so impounded will be taken by tunnel to the Lednock generating station in Glen Lednock. This generating station will be on the shores of a new loch to be formed by a dam across the River Lednock near Bovaine. From this loch, into which additional water from the Almond, Boltachan and other streams will be diverted by aqueducts, a tunnel and pipeline will supply the St. Fillans generating station 830 ft. below, on the shores of Loch Earn. The St. Fillans generating station will have a capacity of 22,000 kW.

The scheme will also make use of the natural flow from Loch Earn. A tunnel, the intake of which will be near the outlet of the loch, will lead water to the Comrie generating station which will be situated on the south bank of the River Farn near Dalhonzie.

Prestressed Concrete Construction

Within the last few years a large number of structures have been built using the prestressed concrete form of construction. In this article F. Walley, M.Sc., A.M.Inst.C.E., outlines the engineering principles involved and shows how they have been applied in practice.

MOST concrete work does not call for a very high compressive strength as the design stresses allowed by the Code of Practice for Reinforced Concrete in bending are quite modest, the highest being only 1,500 lb. per sq. in. for a 1 : 1 : 2 mix. It will be found that increasing the stresses, if allowable, would lead to a section having a high percentage of steel which it might be difficult to place since the stress in the steel is limited to 27,000 lb. per sq. in. even with the high-tensile varieties. This limitation has been imposed, not because it is impossible to get steel of higher tensile stress, but because the extension of steel at stresses above this value would lead to what are considered to be dangerous cracks in the structure —dangerous in the sense that corrosion from fumes, moisture, etc., could take place. These cracks occur because of the relatively low tensile strength of concrete and the small elongation that occurs before failure in tension. Improving the quality of the concrete does improve the tensile strength but not to a marked degree. Thus until a concrete is invented which has a high tensile strength or which will undergo large strains before failure, the limit has probably been reached in the economy of reinforced-concrete construction. Progress is barred because of the inherent properties of the materials, particularly the low tensile strength of concrete.

This statement of the case is not new, and its truth has been realised from the infancy of reinforced concrete. Thus towards the end of the nineteenth century various continental engineers had proposed a solution to the problem which, in fact, was what we now call prestressing. All the solutions, or rather the practical applications of them, bore little fruit for they had outstripped research into the fundamental properties of the materials they employed.

The solution to the problem, on paper, was in essence a simple one; since concrete is weak in tension but strong in compression then the stress distribution in a concrete member must be so arranged that the concrete is never allowed to be in tension under working load or at any rate is kept within prescribed limits. In other words, if a bending tensile stress under a working load of say, 1,000 lb. per sq. in. were to be developed in the lower fibres, then, before the load is applied a compressive stress of this amount must be applied at the same point. The combination of these two stresses would mean that under the working load no stress is developed and hence the concrete does not crack.

It was to prove difficult to achieve this result permanently, and the problem was not finally solved until the late 'twenties and early 'thirties of this century. The early investigators induced the desired compressive stresses by stretching steel rods in the concrete and anchoring them against the ends of the member. This they found had a beneficial result and delayed the onset of cracking, but in the course of time the beams they had " improved " were no better than corresponding reinforced concrete beams. It was not until M. E. Freyssinet, in France, in the 'twenties showed the reason why this happened, that it was possible to make progress along these lines. M. Freyssinet not only showed by research why this occurred but also proposed the solution which now bears his name. He discovered that concrete is not elastic, but that under constant load the strains increase and are not wholly recoverable — the so-called creep phenomenon. This loss, together with other losses, such as shrinkage, cannot be ignored or avoided; and due allowance must be made for them. If, then, prestressing is to be obtained by straining steel wires or rods against concrete so that the compression in the concrete equals the tension in the steel, an extra stress must first be induced in the concrete and the steel, so that when the losses have taken place there is still sufficient stress left in the concrete at the desired points. The stresses used by the early investigators were so low that they were all lost by the shortening of the concrete, and the steel returned to its original length.

To give some idea of the order of the strains and stresses involved in this process the following data may prove useful. The shrinkage strain may be as high as $0{\cdot}3 \times 10^{-3}$ in. per in., and the creep under a stress of 1,500 lb. per sq. in. may be $0{\cdot}45 \times 10^{-3}$ in. per in. The total shortening is, therefore, $0{\cdot}75 \times 10^{-3}$ in. per in.; if a value of 27×10^{6} lb. per sq. in. is assumed for Young's Modulus of the steel then the loss in stress in any steel used would be $0{\cdot}75 \times 27 \times 10^{3}$, which equals 20,000 lb. per sq. in. It will thus be seen that a stress of at least this value would have to be used in the wires before any permanent effect could occur. Even when high stresses are used in the steel this loss can amount to an appreciable quantity. For most prestressed work the loss is about 15 per cent. for steel stresses of 120-130,000 lb. per sq. in. This was the solution proposed by M. Freyssinet who was the first to use high-tensile steel wire. Since the concrete is put into a permanent state of compression and does not crack, the only limit to the steel stress which may be used is that imposed by the tensile strength of the wire available; the higher the latter, the higher is the allowable stress in the steel. This is also true for the concrete. The inherent weakness of concrete—its tensile strength—is no longer a drag on design and so use can be made of concrete in a more economic way. Thus research into these matters,

i.e. increasing tensile strength of steel and the compressive strength of concrete, is encouraged by the knowledge that if discovered they can be directly employed in reinforced concrete work. The barriers are down and already concrete has been produced with an ultimate compressive strength of 15,000 lb. per sq. in. and even higher, while steel wire can be obtained with an ultimate strength of up to 160 tons per sq. in.

Such then is the background of prestressing. It may prove useful at this point to give a definition of prestressed concrete:—

"A member is said to be prestressed when it is subjected to a system of forces before or during the application of any external loads so that the stresses due to these forces, combined with the stresses due to the external loads, shall be such that the member will carry the loads in perfect safety for an indefinite period of time without any risk of the concrete cracking."

The next point to be considered is how this system of forces may be calculated. First of all it must be sufficient in size to reduce the anticipated tensile stresses to a safe value—this is implicit in the latter portion of the definition. If a simply supported rectangular beam carrying a uniform load is considered, bending stress distributions as shown in Fig. 1 are induced at various points along the beam. These, for a homogeneous material, may be readily calculated using the well-known formula relating stress, the applied moment and the properties of the section, i.e. $\frac{p}{y} = \frac{M}{I}$, where the letters have the usual meanings.

Concrete under normal conditions is not homogeneous, since, as has already been seen, it cracks at a low tensile stress and in general the stress distribution shown at *C-C* does not exist. If the tensile stress shown in the diagram is assumed to be carried by a reinforcing rod then the ordinary assumed stress distribution at working load for reinforced concrete is obtained. Since, however, it is not intended that the concrete shall crack when prestressed, it may be assumed that the section is homogeneous under working loads and the whole section may be used for calculation purposes without worrying whether part of it should be discounted. This fact alone so simplifies the design problem that normal reinforced concrete seems difficult by comparison.

If a uniform compressive stress distribution is induced in a concrete member of equal amount to the maximum anticipated tensile stress, then instead of the stress distributions shown in Fig. 1 for a beam under full working load those shown in Fig. 2 will be obtained. This uniform stress can be induced by applying a force acting at the centroid of the section at every point in the section. The prestress distribution is used for various "structures" such as poles where the load may come from any direction, beams continuous over a number of supports, where reverse moments are possible, etc. It will be seen, however, that this system of stress distribution suffers from a serious disadvantage, that under working load a stress is induced in the compression zone of twice the value which would occur if no prestress had been applied, and in this condition a limit would be set by the compressive strength of the concrete. If the direction of the applied load is known, as in a beam, uniform prestressing is uneconomic since compression is created in a place where it is not required. To create this prestress, steel has to be used; therefore not only is concrete being wasted, because only half the allowable stress can be used, but also steel.

An inspection of Fig. 1 will show the requisite stress distribution. To avoid the tension in the bottom fibres and not increase the compression in the top fibres beyond that induced by the applied load, a triangular prestress distribution is required varying from zero stress in the top fibres to the anticipated tensile stress in the bottom fibres. In this case the stress distribution as shown in Fig. 3 is obtained.

It will be seen that the stress in the concrete is everywhere compressive and that the maximum value is only half that shown in Fig. 2. This prestress distribution is no more difficult to obtain than a uniform one. The force, instead of having its centre at the centroid of the section—thus creating a uniform stress equal to $\frac{T}{A}$ where T is the force and A the cross-sectional area of the concrete—is applied at a point below the centroid and gives rise to a stress distribution made up of two parts, one due to the direct compression $\frac{T}{A}$ and the other to the moment Te (Fig. 3). The moment Te may be substituted for M in the formula previously given and the stress distribution calculated if the properties of the section are known. Combining the two parts of the stresses algebraically the stress at any point due to the

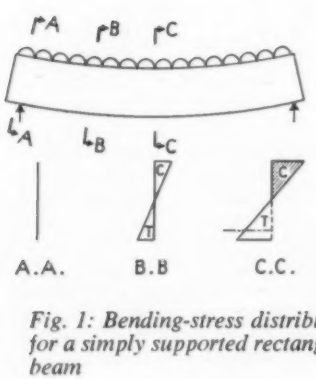


Fig. 1: Bending-stress distribution for a simply supported rectangular beam

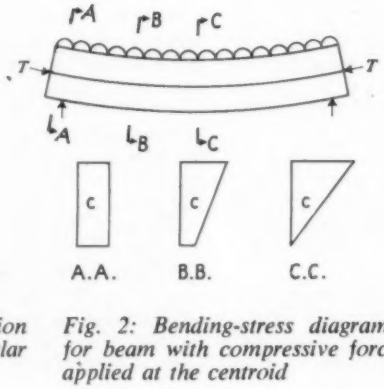


Fig. 2: Bending-stress diagrams for beam with compressive force applied at the centroid

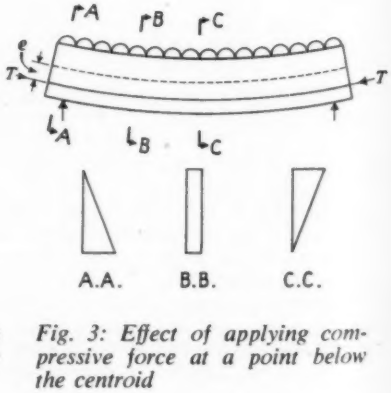


Fig. 3: Effect of applying compressive force at a point below the centroid

eccentric force T will be, in the top fibres,

$$\frac{T}{A} - \frac{T\,e\,y}{I}$$

and in the bottom fibres,

$$\frac{T}{A} + \frac{T\,e\,y}{I}$$

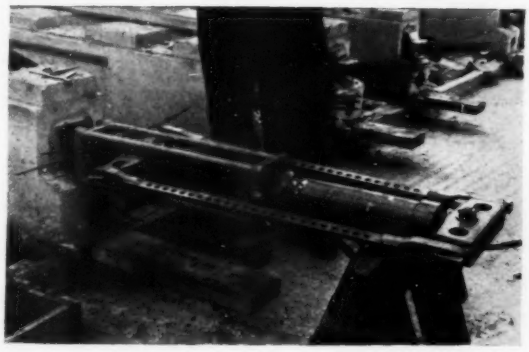
If it is required that the stress distribution in the top fibres should be zero then,

$$\frac{T}{A} - \frac{T\,e\,y}{I} = 0$$

and, therefore, e, the eccentricity of the prestressing force, must equal

$$\frac{I}{Ay} \text{ or } \frac{k^2}{y}$$

where k is the radius of gyration of the section. If the section is rectangular the reader will quickly see that this is none other than the middle third rule as used in the simple design of foundations, dams, etc. Knowing e and the anticipated tensile stress the value of T may be quickly found from the second equation.



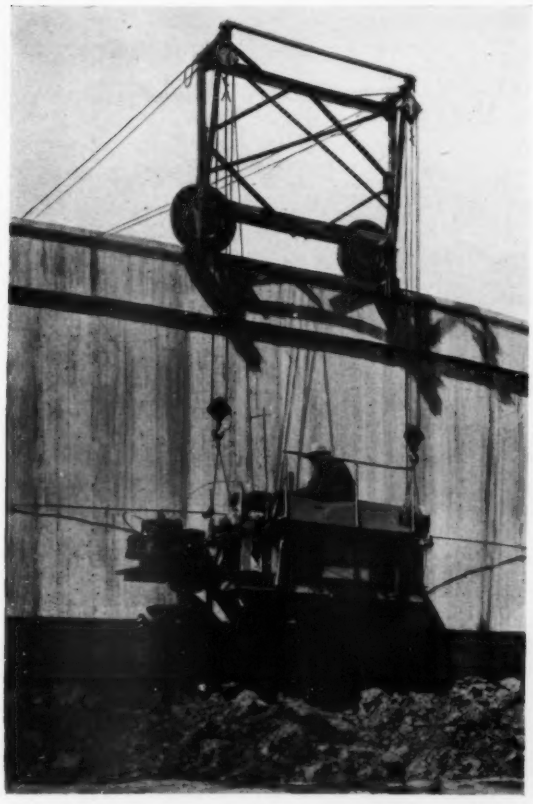
These two equations are the basis of all prestressing calculations. It will be useful at this stage, however, to go on and derive the four fundamental equations which satisfy the four conditions which are met in the design of any structure. Not all sections are symmetrical about the X-X axis so that the stress in the top fibres will not necessarily equal the stress in the bottom fibres. Nor will all the load be applied at once; the structure has to be erected before it can carry any load and also, as has been shown already, the prestress is reduced in the course of time by creep and shrinkage. One has to be sure, therefore, that the stresses in the top and bottom fibres of the beam, both during erection and subsequently under full working load and when all losses have taken place, are within the allowable prescribed limits. These conditions may readily be expressed mathematically. It will be assumed that the distances from the centroid of the section to the top and bottom fibres are y_1 and y_2, I the moment of inertia of the section, k the radius of gyration of the section, A the cross-sectional area of the section, T the prestressing force, e its eccentricity. It will further be assumed that C_{Dt} and C_{Db} are the stresses in the top and bottom fibres, due to the dead loads acting when the prestressing is being carried out and C_{At} and C_{Ab} are stresses caused by the superimposed applied load again in the top and bottom fibres. The allowable stresses must also be given and these will be assumed to be C_t and C_c for tension and compression respectively.

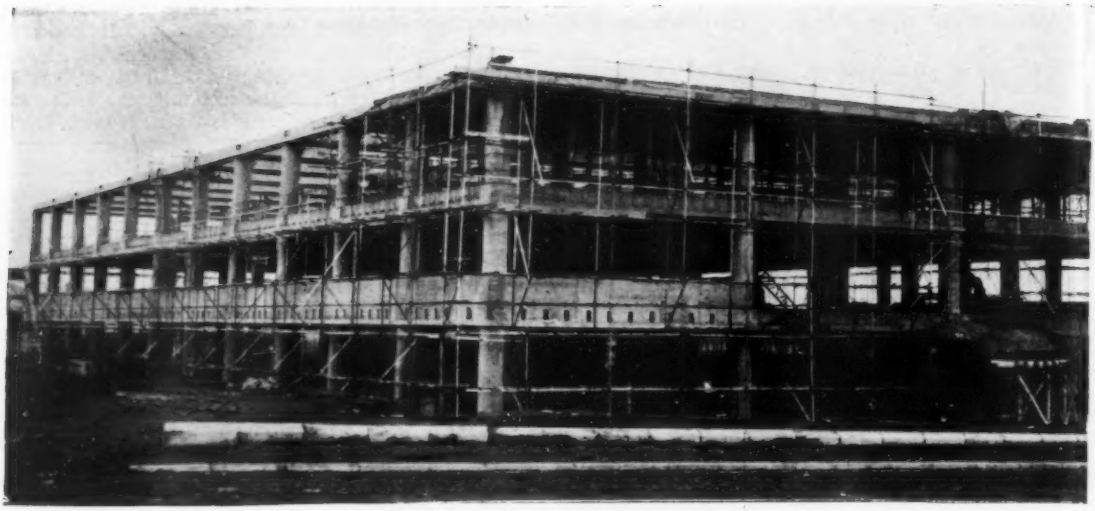
The four equations may be written down, the first to satisfy the condition that when only the dead loads are acting the stress caused by the prestressing in the top fibres does not exceed the allowable tensile stress in the concrete. (The dead load of the beam will always act when the prestressing force is not at the centroid of the section since the force will tend to

Fig. 4 (left): Anchorage device and tensioning jack for Freyssinet system (Prestressed Concrete Co. Ltd.)

Fig. 5 (bottom left): Jack and anchorage used in the Magnel-Blaton system (Stressed Concrete Design Limited)

Fig. 6 (below): Circular tank post-tensioned by winding on steel wire (Preload Corporation)





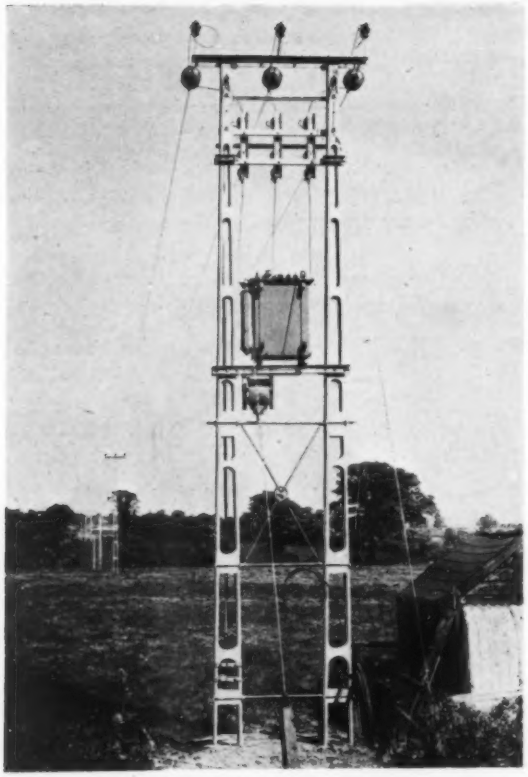


Fig. 7 (above): Three-storeyed building having floors and roof in prestressed construction (Crown Copyright reserved. Reproduced by permission of the Ministry of Works)

Fig. 8 (left): This illustration shows prestressed electricity transmission poles in use by the Eastern Electricity Board

hog the beam and so make it simply supported about its two ends.)

$$+\left\{\frac{A}{T}-\frac{I}{T\ e\ y_1}\right\}+C_{Dt}=-C_t$$

Secondly, to satisfy the condition that not too much compression is created in the bottom fibres during prestressing:—

$$\left\{\frac{T}{A}+\frac{T\ e\ y}{I}\right\}-C_{Db}=C_c$$

Thirdly, to satisfy the condition that not too much compression is created in the top fibres under full load and when all losses in the prestress have taken place

$$+n\left\{\frac{T}{A}-\frac{T\ e\ y_1}{I}\right\}+C_{Dt}+C_{At}=C_c$$

Fourthly, to satisfy the condition that not too much tension is created in the bottom fibres under full load and when all losses in the prestress have taken place,

$$+n\left\{\frac{T}{A}+\frac{T\ e\ y_2}{I}\right\}-C_{Db}-C_{Ab}=-C_t$$

It is not usually a quick matter to obtain a unique solution to these four equations nor is it always necessary. It is usually sufficient to satisfy the first and fourth equations and check that the solution obtained gives reasonable stresses for the second and third conditions. The value of n is about 0.85 for post-tensioned work and a less value for pretensioned work, although both values alter, depending on the concrete and the initial stress in the steel.

Design Considerations

It is not possible in this short note to show what the solution of these equations leads to, but the reader may manipulate them for himself to show that if n is put equal to 1 then the section required depends only on the applied superimposed load and not the dead loads of the structure. Furthermore, the section required is arrived at not by using the allowable compressive stress but the sum of the allowable compressive and tensile stress; putting n equal to less than 1 only modifies the above statements by a small amount. It will thus be seen that prestressed concrete will show considerable advantages where large dead loads are encountered, as in long span work.

All that the above equations do is to give the shape and size of the stress distribution required to cancel

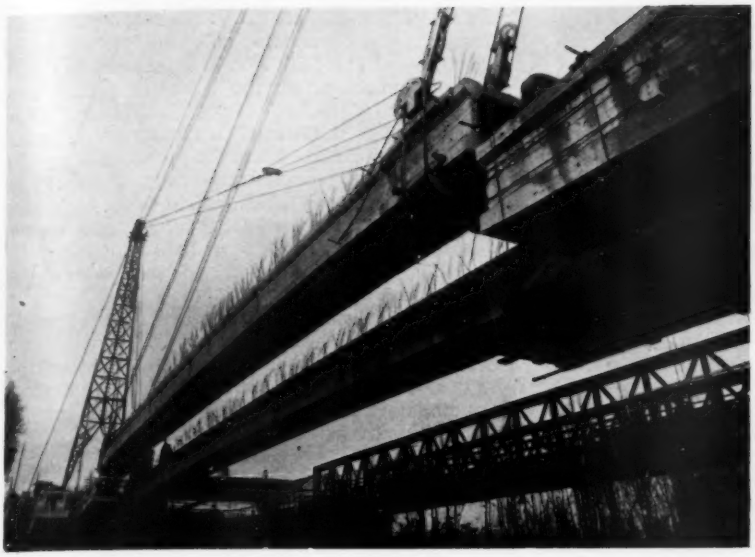


Fig. 9: The Luzancy bridge under construction, using the Freyssinet system (Prestressed Concrete Co. Ltd.)

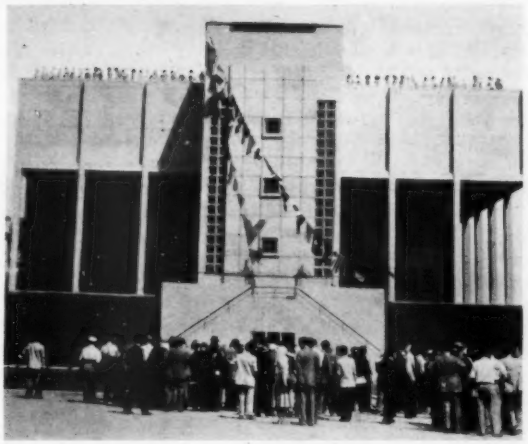


Fig. 10: A reservoir in Orleans constructed on the Freyssinet system (Prestressed Concrete Co. Ltd.)

out the stress distribution caused by the self weight of the beam and the applied superimposed load, taking due account of the time at which they are applied.

One further but very important point should be mentioned. The provision of the prestress to counteract the tensile stresses developed at the centre of the beam must necessarily produce compression at the ends of the beam where, in general, high shearing forces will be found. The interaction of the compressive stress with the shearing stresses (usually) reduces the principal tensile stresses to a low value so that little is to be feared from shearing stresses even in sections with very thin webs. This means that whereas in reinforced concrete large sections may be required to absorb these stresses, in prestressed concrete the section may be determined solely from bending considerations. In post-tensioned work the prestressing cables may also be bent up towards the end to reduce tensile stresses which would be created by the prestress in the absence of compressive stresses caused by the dead load of the structure, and this, too, reduces the shear forces. It is difficult to enumerate all the changes that occur because of prestressing, but nearly all of them are easily calculated by anyone with a knowledge of strength of materials, since the material may be considered as homogeneous within the working range.

Practical methods of prestressing

After this brief excursion into theory, the methods of applying these forces must be examined. The methods of post- and pretensioning have already been mentioned and they will be described in that order.

Post-tensioning, as its name is intended to imply, is the method of prestressing where the tensioning of the wires, which cause the prestress, takes place after the concrete has been cast. The method is sometimes also called the non-bonded system. In this method the concrete member is cast either with the prestressing wires in their correct position in the member but separated from the concrete by a wrapping of metal or paper, or by leaving prepared holes through which the wires are threaded later. In both cases the concrete is allowed to harden until the desired concrete compressive strength is reached. This is usually of the order of 5,000 lb. per sq. in. The wires are then anchored at one end of the beam and at the other end are pulled by a jack acting against the end of the member. The jack compresses the concrete and when the desired compression has been reached in the concrete (measured by the tension in the wires) the wires are anchored. The compression in the concrete is thus maintained by the tension in the wires.

Two methods of carrying out the above process are in common use. The first is due to the originator of prestressed concrete, M. Freyssinet, who uses a double-acting jack exerting a force of 20 tons. The prestressing cables are usually made up of 8, 10, or 12, 0.2 in. diameter wires, and these are anchored by wedging them in the cylindrical head of the jack. Oil is pumped into the cylinder and the head is forced away, pulling the wires. When they have been stretched sufficiently a second piston operates, driving home a conical wedge which anchors them in a special anchor block. Both the cone and anchor block are made of concrete, the block being reinforced with spiral wire. A hole is left in the cone through which grout may be injected when the prestressing has been completed. The cables in this process are usually placed before concreting but separated from the concrete by wrapping them in a thin metal sheath. The anchorage

device together with the jack is shown in Fig. 4.

A second method of post-tensioning is the Magnel-Blaton system which employs a smaller jack stretching two wires at a time. The wires are anchored in a sandwich plate which holds eight wires. Cables of up to 64 wires can be made and anchored by placing sandwich plates on top of each other. Special distribution plates are used to relieve the high stresses that occur under the plates and distribute them to the concrete member. In this method preformed holes are usually used and the cables threaded through after the concrete has hardened. These holes are formed by using withdrawable solid rubber cores. A jack and anchorage are shown in Fig. 5. In this method 0.276 in. diameter wire can also be used. Both methods are usually used in site work and civil engineering work in general.

A third but specialised form of post-tensioning is that due to the Preload Corporation of America, used in prestressing circular tanks. In this method concrete tanks are constructed with only nominal steel, and the prestressing is carried out by winding on steel wire in a stressed state in the form of a continuous spiral. A tank being prestressed in this way is shown in Fig. 6.

Post-tensioning has also been carried out using large diameter rods with screwed ends and a certain amount of work using this method was done by the Germans at the beginning of the late war. It has been intermittently used in other countries since that time. Its usefulness is limited by the low ultimate strengths obtainable in large diameters of steel rods.

Pretensioning

In this method the wires are tensioned before the concrete is cast and the stress is maintained in the wire by the bond between the wire and concrete, augmented by the slight swelling which takes place in the steel when it tries to return to its original length. In this system usually small diameter wires are used of the order of 12 s.w.g., although thicker wires may be used if attention is paid to obtaining a good bond. Since the wire diameters are smaller, higher ultimate-strength steel can be obtained and hence higher stresses may be employed. The concrete is cast around the stressed wires and when it has reached the desired strength the wires are cut. The steel shortens until the force in the wires is balanced by the opposing force in the concrete. This reduction in stress must be taken into account in addition to the losses due to creep and shrinkage and is to this extent "inefficient." The method, however, is extremely useful for precast units and short-length beams where the provision of special anchorages would be relatively costly. It should be remembered that in post-tensioned work the anchorage and prestressing operations are the same whatever the length of the beam. For normal loading it is usually more economical to precast and use pretensioned units for spans up to 35 ft. For heavy loads, however, the number of small-diameter wires required might make this process unworkable.

Before illustrating the practical applications of this form of construction some word should be said about the materials used. The steel has a high carbon content and may be obtained in the range:—

0.276 in.	90-100 ton per sq. in.
0.20 in. down to 16 s.w.g.	100-110 „ 140-150 „

The 0.1 per cent. proof stress of this steel should be 70 per cent. of its ultimate strength; the shape of the stress-strain curve except for certain steel now coming into the market is only linear over a small range and no true value of E can be given.

The concrete used for this work should be of good quality, and a cube strength of 6,000 lb. per sq. in. should be obtained in seven days. To get such a

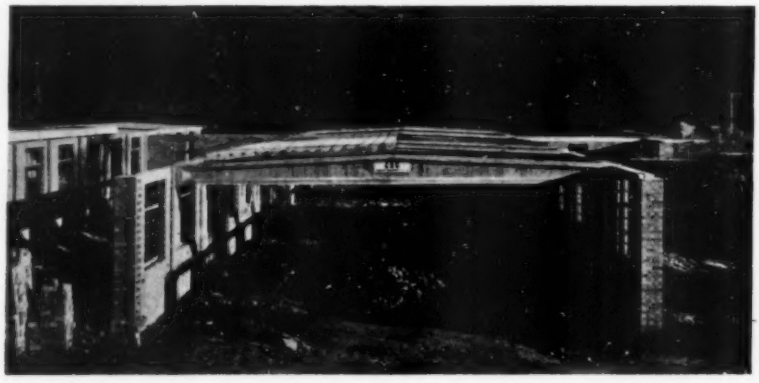


Fig. 11: Prestressed precast beams used in office construction (Crown Copyright reserved. Reproduced by permission of the Ministry of Works)

Fig. 12: Prestressed concrete valley beams in roof construction (Stressed Concrete Designs Limited)

strength is not difficult, provided strict control is exercised on the job and a low water-cement ratio is used. To obtain a workable concrete a mix of about 1 : 1½ : 3 is usually employed with a W : C ratio of 0.35 - 0.45. Such a mix requires vibrators to place it satisfactorily. For precast work steam heating and pressure is sometimes applied to obtain early-strength concrete.

Many hundreds of works have now been carried out in prestressed concrete in the world and every day more jobs are added to the list. In this country alone some 40 jobs have been completed or are being constructed excluding those employing only simple prestressed flooring or roof units. It is possible to illustrate very few of these in this note.

Fig. 7 shows a three storeyed storage building which is now nearing completion. The floors and roof are of prestressed concrete, the columns of normal reinforced concrete work.

Fig. 8 shows electricity transmission poles in use by the Eastern Electricity Board; these were manufactured on the pretensioned system.

Fig. 9 shows the Luzancy Bridge in France. It has a span of 250 ft. and the Freyssinet system was used for its construction.

Fig. 10 shows one of three reservoirs erected in Orleans on the Freyssinet system. The reservoir has a capacity of 1,600,000 gallons.

Fig. 11 shows the use of prestressed precast beams for office building; these beams are of 38 ft. length and manufactured on the pretensioned system.

Fig. 12 shows the use of prestressed concrete valley beams in roof construction.

The uses of prestressed concrete are many and for lack of space many types of structures have not been illustrated in these photographs. It is a form of construction which has come to stay, not that it will supplant all other forms of construction, but it will be used where its advantages may be exploited. Among these advantages may be classed the following:—

1. A form of construction is obtained which is always free from cracks — even hair cracks, under full working load. This means that it may be used to advantage in situations where corrosion is a danger.
2. Because of horizontal precompression due to the prestress principle, tensile stresses are reduced and shear resistance is obtained without the use of large webs or heavy reinforcement.
3. Since less main steel is used and binders and shear steel are usually unnecessary it is possible to use and place much better concrete than can be normally used in reinforced concrete. Thus higher comparative strengths may be used with consequent reduction in the weight of the construction.
4. This not only saves material in the prestressed construction but saves dead loads with consequent saving in supports and foundations.
5. In post-tensioned systems lighter sections may be used since only a very small part of the weight of the dead-load construction has to be taken into account in determining the concrete section required. For this reason very much longer spans can be built in prestressed concrete as compared with reinforced concrete, the dead loads being very much smaller.
6. For precast prefabricated construction the advantages of a reduction in self-weight of the unit are obvious.
7. By the use of precasting and using composite structures a great reduction is made in the amount of shuttering required.
8. There is in addition a saving of steel used as compared with other forms of construction.

Portugal plans ahead

Completion of the Castelo do Bode dam, on Portugal's Zezere River marks an appreciable step in the progress of that country, the oldest of Britain's allies, towards her objective of fully developing her extensive water-power resources. Already the water harnessed to produce industrial and domestic power represents over half the country's total resources.

If these hopes are realised it will mean the completion, within a span of about 14 years, of a great concept that had its practical origin about seven years ago. The ultimate aim is a network of power stations and transmission lines which will cover the country and ensure adequate supplies of electricity to all parts.

Work both on the Zezere and the Cavado rivers began shortly after the close of the last war, the installations on the former river involving expenditure of about 250 million escudos (£3 million), costing more than double those planned for the Cavado. The Castelo do Bode dam has already been described in detail in *Water Power* and the next big dam in the national development plan, that of Villa Nova, on the Cavado, will ultimately provide another 150 million kWh a year, against the 300 million kWh of the Castelo do Bode project. Both the English Electric Company and Metropolitan-Vickers are associated with work on this second dam, which it is hoped will be completed by the end of the year.

But the Ministry of Public Works in Lisbon has even more ambitious schemes in mind. Some of these were mentioned by the Minister (Senor Ulrich) a few weeks ago, though at present they are still only in embryonic state. Nevertheless, given freedom from international upheaval there are good grounds for anticipating that these schemes will be well on the road to completion by the end of 1956 by which time about 2,500 million kWh a year will be produced from water power. While the Cavado plan looms largest in the devedopment outlook at the moment other developments are also foreshadowed on the Douro, Cabril and other rivers. These new schemes, according to official sources will cost in the region of £20 to £25 million.

The projects will, of course, rank for aid from the organisations associated with the Marshall-Aid plan, for they mean that, in the long run, this important though small country will be getting its power at a relatively low cost when most other products are showing an alarming advance in price. This point doubtless was fully appreciated and appraised by the Minister for Economic Affairs, Dr. Cortes, when he announced recently his conviction that ultimately it will be possible to win 9,000 million kWh per annum of electric power from water power. Marshall-Aid will be made available through the Economic Co-operation Administration which has given its approval for utilising funds lying in the Bank of Portugal.

Thew-Lorain
25 Ton Moto-Crane

THE availability of two new Lorain machines, each rated at 25 tons lifting capacity on outriggers at 10 ft. radius, and capable of working with 130 ft. of boom, is announced by M. B. Garber, General Sales Manager of The Thew Shovel Company, Lorain, Ohio. These machines are known as models MC-504

View of the MC-504W "Moto-Crane" arranged as 30 ft. jib lifting crane

and MC-504W and will be marketed under the trade name "Moto-Crane," the registered trade mark of The Thew Shovel Company. The turntable is driven by a 6-cylinder engine, the resulting power being first delivered through a Twin Disc hydraulic coupling and thence by a multiple-strand roller-chain drive to the operating mechanism. The coupling includes a plate-type disengaging clutch which permits the disengagement of all mechanism for lubrication or adjustment without stopping the engine. In addition to absorbing sudden shock loads and thus relieving the operating mechanism and cables of excessive stresses, the fluid coupling enables the raising and lowering of loads at variable speeds under control of the engine throttle. This permits precision hoisting to be done at very slow speeds, with a smoothness difficult to obtain through friction-clutch control.

The new machines may be equipped with any of the following interchangeable boom equipment. The crane boom consists of two 15 ft. all-welded sections, pin-connected together with four pin and clevis connections. Various centre sections, of similar design and connections, are available permitting the main boom to be extended to 100 ft. in length. The boom head is equipped with three main boom-head sheaves, plus auxiliary deflector sheaves, that permit reeving up to six parts of the hoist line without the use of a top block. In addition, 15 and 30 ft. tip extensions are available to extend the boom to a maximum overall length of 130 ft. Standard equipment for the lifting crane includes a lowering device which affords a wide range of power-controlled boom lowering speeds; hook block; swing brake; twin boom stops of cable and mechanical types; and floating boom harness for eight-part boom hoist line. A third drum is available as extra equipment on lifting cranes.

Shovel booms of 21 ft. or 19 ft. in length are available. Each is equipped with a shovel dipper of 1 cu. yard capacity carried in a one-piece, all-steel, square dipper stick, 17 ft. long.

The "cable-miser" type dragline has interlocking or "geared" sheaves for synchronised, cable-saving sheave action, and the hoe consists of a 19 ft. long boom of all-welded construction with a gooseneck or offset to give greater digging ranges. Hoe dippers are available in 48 in. (1 cu. yard), 46, 44, 40, 36, 30 in. cutting widths.

Two carriers are provided: the MC-504W is a "wide track" model consisting of a three-axle carrier, 118 in. in width over rear tyres, with driving power applied to the two rear axles. If required a front driving axle may be installed to make the MC-504W a "6 × 6." The advantages of the "wide track" model is the exceptionally higher lifting capacity developed when working "on rubber" without use of outriggers. They are claimed to lift more, or reach farther, without requiring setting of outriggers and subsequent loss of mobility. They are thus suited to jobs requiring constant and instant travel combined with heavy-duty lifting.

The MC-504 model is an identical machine apart from the narrower width (102 in. over the rear tyres) and the fact that it is only available with power on the two rear axles.

Both carriers have many features in common, *e.g.* the carrier frames are designed specifically for shovel and crane use and consist of deep, wide side members of internally reinforced box-sections, joined together by front bumper, cross bracing, two outrigger boxes and mounting plate into a single-piece weldment. Power for the carrier is supplied by a separate six-cylinder 220 h.p. engine, which is coupled to a Fuller main transmission mounted integrally with the engine, to give five forward speeds and one in reverse. A two-speed Timken Detroit transfer case is mounted amidships which, when used in combination with the main transmission, gives a total of 10 forward speeds and two reverse speeds. The two rear axles are Timken Detroit double reduction gear driven axles mounted in tandem and connected with an intermediate propeller shaft to provide a "through drive" between axles. This drive provides maximum traction at all times as torque is always transmitted to the axle having tractive effort. High traction differentials in the rear axles also aid in giving improved tractive effort. All the rear wheels are equipped with Bendix-Westinghouse air brakes operated by constant lift cams. Front brakes are available for all models. The parking brake is a 16 in. diameter double-disc type mounted on the propeller shaft. All models are equipped with

Bendix-Westinghouse air-assisted steering which is synchronised with and functions automatically with manual steering as soon as the driver "leads" the wheel; this, of course, greatly reduces the steering effort.

Compendio de esta Edición

Entrenamiento de Ingenieros Hidroeléctricos. Por Profesor J. A. Harle, Jefe del Departamento de Ingeniería Eléctrica de la Universidad de Alberta, Canadá (Véase la página 125).

Un ingeniero hidroeléctrico tiene que poder contar con un entrenamiento muy sólido en muchos aspectos distintos y tiene que estar bien versado en asuntos económicos y de ingeniería. Como preparación preliminar debería ser un ingeniero industrial o electricista y esto lleva consigo conocimientos muy completos en su propio idioma. Los estudios generales deberían comprender física, química, matemáticas, mecánica, economía política, geología elemental, dibujo lineal y mecánico, agrimensura, materiales de ingeniería, ingeniería mecánica e hidráulica. Los ingenieros industriales también deberían estudiar la mecánica de las tierras, cimientos y estructuras de tierra, la teoría de las estructuras, hidrología y suministros de agua, construcciones de ingeniería, ingeniería eléctrica elemental, ingeniería hidráulica y conducción de aguas cloacales. El ingeniero electricista también debería hacer un estudio de maquinaria de corriente alterna y de transmisión de energía eléctrica. Se reproducen tablas con programas de cuatro cursos para ingenieros industriales y electricistas y se recomienda que al final de estos cursos los estudiantes ingresen en una empresa hidroeléctrica para fines de entrenamiento. Se logran ventajas muy obvias como resultado de viajes de estudio y de experiencia en otras organizaciones.

Transmisión de muy alta tensión. Por Dr. S. Whitehead (página 128).

El autor de este articulo, el Director de la Electrical Research Association (Asociación de Investigaciones Científicas Eléctricas) discute las ventajas y limitaciones de los trabajos cooperativos de investigación científica eléctrica, haciendo referencia de manera muy especial a problemas de transmisión de muy alta tensión. El autor presenta el argumento que en asuntos de esta naturaleza la asociación de investigaciones científicas tiene que ocuparse menos del diseño de los equipos propiamente dichos y tiene que prestar una mayor atención a los problemas relacionados con su utilización. Como consecuencia, los trabajos de investigación científica han sido encaminados con miras al establecimiento de principios básicos y al estudio de los materiales empleados para las piezas componentes.

Energía Eléctrica en España, 1950. Por M. Castilla, Ingeniero Industrial de Hidroeléctrica Española (página 134).

Un país faltado de carbón de hulla o petróleo es muy natural que trate de sacar el provecho máximo posible de su energía hidráulica; como consecuencia, los desarrollos hidráulicos en España datan del año 1875 y en época tan remota como el año 1900 se construyó una línea de transmisión de 66 kilovoltios. Desde entonces los progresos realizados han sido de naturaleza regular y progresiva, pero de manera muy especial durante estos últimos años la industrialización aumentada del país y el aumento de la población han proporcionado un estímulo para la construcción de nuevas instalaciones. Se reproduce una tabla de captaciones hidráulicas y de instalaciones generadoras de fuerza motriz bajo construcción y dan una idea muy impresiva de la gran obra que se está realizando. Se hace mención de las dificultades especiales que tienen que vencerse, especialmente debido a las extraordinarias variaciones en el caudal de los ríos, causadas por las peculiaridades del clima. Por ejemplo, se cita el caso de que el flujo de un río era de 20.000 millones de metros cúbicos en 1936 y tan sólo ascendió a 3.000 millones de metros cúbicos en 1949. Con miras a contrarrestar los efectos de estas variaciones se están construyendo grandes pantanos y las instalaciones son interconectadas entre sí con el objeto de que la energía disponible pueda ser aprovechada de la manera más eficiente posible. Se facilitan detalles de la nueva instalación de Cofrentes sobre el río Júcar, la cual se calcula que está dotada de una producción anual de energía de 250 millones de kilowatios-hora.

Un desarrollo del Ródano (página 132).

Se reproduce una muy breve descripción del trabajo que se está realizando en la sección Donzere-Mondragón del Ródano, lo cual lleva consigo la construcción del mayor canal de Europa.

El Cuarto Congreso de Presas Altas (página 143).

Se facilita un resumen de las discusiones de la Conferencia de Presas Altas que no podrán menos que ser de interés para los Ingenieros hidroeléctricos. De manera especial se hace referencia a la descarga de avenidas, taludes exteriores, presas rellanadas de tierra y de roca, sedimentación y otros problemas relacionados. También se presentó un gran número de memorias versando sobre las cualidades del hormigón para presas altas, incluyendo estudios de deslizamiento molecular y extensibilidad, y los efectos de graduación y de arrastre de aire; hendiduras y grietas debajo de presas y el empleo de hormigón preparado en serie hecho de puzolana, escoria de alto horno, cal hidráulica y otros materiales.

Construcciones de Hormigón Previamente Encogido. Por F. Walley, M.Sc., A.M.Inst.C.E. (página 149).

Se hace una descripción breve de los principios de ingeniería afectados y se describen y discuten los diversos métodos de encogimiento previo comúnmente empleados. Entre las ventajas que se reivindican pueden citarse: se eliminan aún grietas de anchura de cabello; la reducción o ausencia de esfuerzo de tracción permite el que pueda obtenerse una resistencia al corte sin el empleo de grandes nervaduras o refuerzos pesados; la cantidad reducida del acero empleado permite la aplicación de mejor hormigón; se economizan materiales y se reducen pesos muertos en los soportes; las reducciones en el peso muerto permiten la construcción de secciones más altas y de mayores espacios de luz; la construcción de moldeado previo puede ser adoptada con el máximo de ventajas posibles.

From the Journals of the technical institutions and other material published in the Press of the World

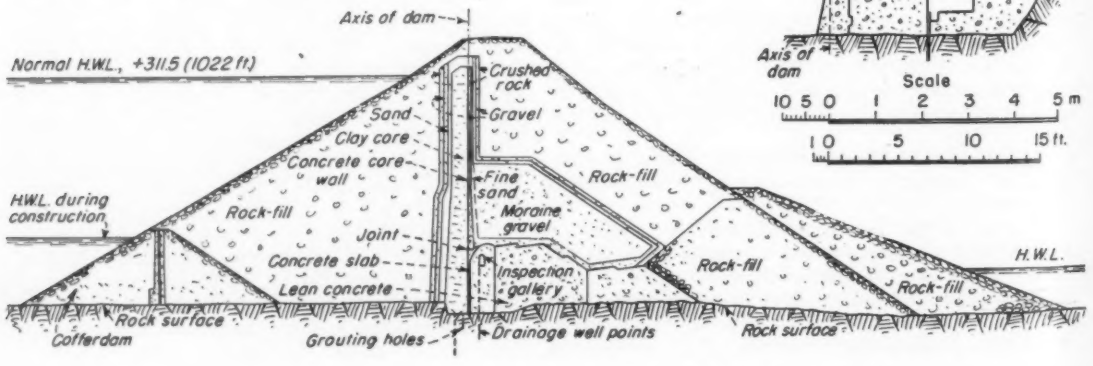
Unusual rock-fill dam

A rock-fill dam with unique design elements has just been completed for the Harspranget hydro-electric project of the Swedish State Power Board. When this project was first proposed in 1918, a concrete arch dam was contemplated but the Swedish State Power Board subsequently decided upon an earth or rock-fill construction in which material excavated from underground power houses and tunnels can be utilised. However, at the Harspranget site, the scarcity of materials from which to build an impervious core made it necessary to depart from normal design practice for rock-fill dams, and a narrow core of rolled clay, built against a thin corewall of reinforced concrete, was used to ensure watertightness.

The design finally adopted, as shown below, provides for a small deflection downstream under water load, and is expected to keep the stress in the concrete below 1,140 lb. per sq. in. Rockfill in the upstream part of the dam was not compacted as thoroughly as that in the downstream side, in order to make certain that it would not settle less than the clay core. Lean concrete at the back of the cutoff wall was used only in the deepest part of the channel. The cutoff, made of a good-grade of concrete, is large enough for the inclusion of an inspection gallery, and supports the corewall which is hinged to it. The horizontal joint between the cutoff block and the corewall, in which the hinge movement takes place, is closed by a steel plate, 12 in. wide and ½ in. thick, welded into a continuous strip across the whole dam.

The main dam is 148 ft. high and 2,650 ft. long, supplemented by a low dam on the left bank 2,130 ft. long. Sound rock underlies the site except at one end, where a faulted zone lies under the surface; fortunately, it is located at a point where the height of the dam is insignificant.

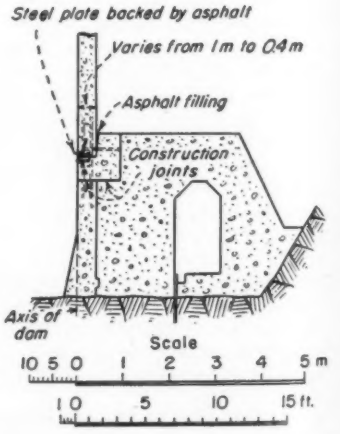
The power station, located in rock, is 275 ft. below the surface and is almost directly under the left extremity of the dam, well removed from the faulting. The power house, 330 ft. by 60 ft., will contain three 96,000 kW generators initially, and space is available for a fourth unit. The draft tubes of the turbines discharge into a single tailrace tunnel 1·8 miles long. — *Engineering News-Record*, Vol. 146, No. 3, Jan. 18, 1951, p. 47, 2 pp., 4 ff.



Repair cableway, Shasta dam

A permanent downstream cableway, together with hoisting equipment, has been installed at Shasta Dam, Sacramento River, Northern California, for placing a steel cofferdam to dewater the apron for repair or inspection.

The 1,380 ft. cableway has a 3 in. dia. main-track cable spanning between steel A-frame towers. A 2½ yd. dragline with 90 ft. boom and 20 ft. jib were used to erect the 130 ft. 2 in. head tower and 60 ft. 2 in. tail tower, the latter being on the west bank of the river with its footing 126 ft. lower than that of the head tower. Cable installation was done step-up, beginning with a ½ in. manila pilot rope. When the 3 in. cable was finally in place, it was anchored at both ends in 330 ton concrete blocks, one 200 ft. down from the head tower, the other 92 ft. from the tail tower. The hoisting machinery, driven by a 150 h.p. motor, is housed directly behind the head tower. Regenerative braking is used, the current produced in braking being fed to a series of resistors instead of back into the lines. When using regenerative braking


Steel plate backed by asphalt
Varies from 1m to 0·4m
Asphalt filling
Construction joints
Axis of dam
Scale
10 5 0 1 2 3 4 5 m
10 5 10 15 ft.

only, the maximum lowering speed is 48 ft. per min.; friction brakes can also be used. Steel parts for the cofferdam, stored half a mile away, are trucked to a point within reach of the cableway for hoisting and hauling across the width of the spillway.

The Bureau of Reclamation say the expenditure involved, $350,000, will be saved many times if repairs ever become necessary but they are hoping the cableway will never be used for other purposes than inspection. — *Engineering News-Record*, Vol. 146, No. 6, Feb. 2, 1951, p. 34, ½ p., 1 f.

Avalanche buries dam work

A 150,000 ton avalanche of ice and snow last October was precipitated into a lake 13,000 ft. above sea level in the Peruvian Andes, caused a flash flood that killed 19, completely destroyed a 1,000 h.p. temporary power plant set up for construction needs, swept away four 10,000 kVA transformers and demolished three 25-ton cranes together with a rock-crushing plant and two concrete mixers, not to mention bridges, roads and railway lines. The layer of silt left by the flood blanketed the dam site up to the gate-house floor level, 50 ft. above the crest of the completed overflow diversion dam. Peru's $10,000,000 Rio Santa hydro-electric project thus loses from 5 to 10 per cent. of the facilities now under construction.

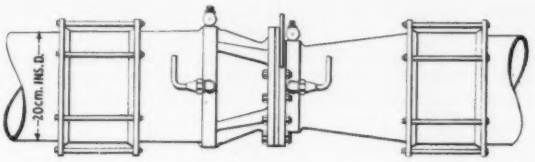
The diversion dam apparently withstood the inundation but it has become so hopelessly buried in the huge volume of silt eroded from the valley farther upstream that the erection of a new dam on top of the original structure has been suggested.

Completion of the portion of the work damaged by the flood at Hidroelectra, 60 miles upstream from Chimbote, where Rio Santa flows into the Pacific, had been scheduled for late 1952, and will it is now estimated, be delayed six months. — *Engineering News-Record*, Vol. 145, No. 20.

Venturi orifice meter

One of the most versatile instruments in use at the Hydraulic Laboratory of the U.S. Bureau of Reclamation in Denver, Colorado, is a flow measuring device known as the portable-orifice Venturi tube. It consists of a short Venturi tube into the throat of which diaphragms with orifices of various diameters can easily be inserted. To change orifices, or simply use the device as a Venturi tube, the flow upstream is shut down, the diaphragm lifted from its slot and replaced by the one desired, whereupon the flow is again admitted. A ring seal automatically holds the diaphragm in position as soon as flow is started and a water pressure of at least two metres is reached in the pipe upstream. The tube is made in one size only, and connects to a pipe of 20 cm. internal diameter by standard slip couplings. Discharges can be measured from 0·0025 to 0·23 cu. metres per second as accurately as with any commercial meter. Pressure taps are located as shown in the diagram—one in the 20 cm. line, the other downstream from the orifice. The tube is always installed downstream from a standard piece of pipe 20 cm. inside diameter, fitted with a flow straightener. Tube and pipe are calibrated together, and can be moved from place to place as a unit. A size larger than 20 cm. would impair the portability of the tube, while it would lose in versatility if made smaller.

The instrument can be used either as a Venturi tube with pipe to throat area ratio of 2 : 1 for the



larger discharges where losses are important; or it can be used as an orifice meter for intermediate and small flows with equal accuracy. Its outstanding feature in laboratory practice is its versatility and the ease with which orifices are interchanged.

The tube is a Bureau of Reclamation design, and is not manufactured commercially. (Contribution of the Hydraulic Laboratory of the Bureau of Reclamation, Denver, Colorado, to *Houille Blanche*, Vol. 5, No. 4, 1950, p. 477, 1 p., 2 ff.).

Rapid placing of a scroll case

The scroll case of a hydro turbine can now be placed in one week instead of five as a result of a new continuous concreting technique applied at Center Hill and World Creek projects of the U.S. Corps of Engineers. Ten shallow pours, three or four days apart, were formerly required to embed the 150-t. scroll case with 1,400 cu. yards of concrete; now the job is done in a single pour in one day by sealing off top and bottom of the case with bulkhead plates. The normal working pressure is then built up by admitting water from the reservoir to the penstock and case.

Advantages gained by this procedure developed by H. B. Elder, resident engineer at Center Hill, are:— (1) Weight of water prevents the case from "floating" upward in the concrete to cause misalignment; (2) Water pressure prestresses the case while the cool water simultaneously shrinks the case in accordance with operating temperature, correcting for elastic deformation; (3) Water-tightness can be checked, and recaulking done under pressure; (4) Water circulation within the scroll case is provided in such a way as to dissipate hydration heat of the concrete; (5) The circulating water helps keep case aligned during concreting by reducing the distortion that would otherwise be caused by ambient temperature changes; (6) Alignment checks can be made while concreting is in progress.

The bulkheads are constructed entirely of commercially available structural shapes with no other machining than drilling the bolt holes. Two eight-legged spiders within the bulkhead hold the speed ring in true round; one is placed directly beneath the top plate attached to the upper bolt circle of the speed ring, and the other directly above the bottom plate attached to the lower bolt circle. The bulkhead steel plates, 1·25 in. thick, are connected by 2·25 in. diameter stay rods about 2·5 ft. apart which extend through stiffeners, mounted on the outside of each plate, consisting of 8 in., 11·5 lb. channels back-to-back. Plates are sealed by ⅛ in. sheet rubber gasket

material, and stay rods by rubber ring gaskets compressed into a bevelled edge of the plates which are welded top and bottom on pipe sleeves fitted around each stay rod. A properly gasketed 6 in. pipe, running throughout the bulkhead centre forms a hole for the piano-wire centre line from which alignment measurements may be taken. Ten evenly spaced slots cut in the outer edge of the top plate permit a micrometer rod to rest on the machined surface of the upper bolt circle of the speed ring so that level checks can be made.

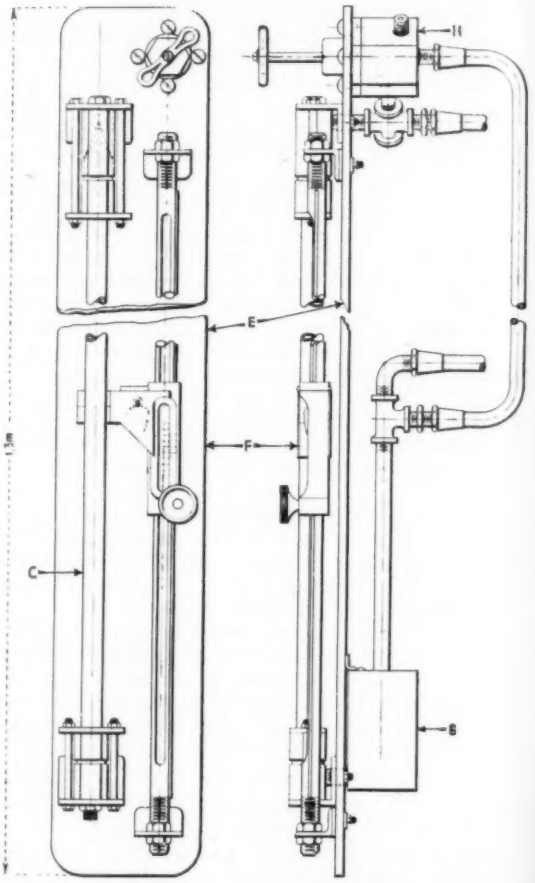
Water is circulated throughout the scroll case by opening a 6 in. valve fitted in the lower plate, and discharging into the draft tube. Weight of the water confined in scroll case is borne by ten concrete saddles spaced midway between the jack supports that carry the case itself. To carry the weight of the confined water the bulkhead is supported by four bents consisting of 8 in. channels, and welded by clip angles to the bottom of the draft tube liner. — *Electrical World*, Vol. 134, No. 28, p. 98, 1 p., 1 f.

Mercury manometer

The diagram appended shows the mercury pot-type manometer perfected over a period of years by the Denver Hydraulic Laboratory of the Bureau of Reclamation for use on Venturi tubes and other closed-conduit water measuring instruments. The general principle differs little from manufactured designs but it has incorporated in it a few convenient features. In the main it consists of a stainless steel reservoir *B*, mounted on an aluminium plate *E*. A high-pressure annealed glass tube *C*, 13 mm. diam. inside, 20 mm. outside by about 1 m. long, is connected to the reservoir by means of a slip-type stainless steel packing gland. The upper end of the glass tube is fitted into a similar packing gland and connects to a special bleeder valve *H*. From experience it has been found that the large gauge glass, which requires about 2 kg. of mercury, is the best method for reducing the amplitude of surges. It was found more satisfactory than throttling by orifices or valves which must have small orifices to be effective. A floating needle valve in the upper packing gland prevents mercury from escaping during unexpected surges. A plug in the top of the upper packing flange is used for filling the gauge, while one in the lower gland permits to drain the mercury, or to adjust its level.

The bleeding of the pipes leading to the gauge is done in an unorthodox manner which, however, has proved quite practical. The large valve at the top of the manometer is, in fact, three valves in one: one port connects to the domestic water supply, which in this case develops a pressure of about 40 lb. per sq. in., while the two other ports connect to the gauge. With the valve in the open position, the pressure on the two legs of the manometer is equalised, and the water is forced under pressure through the gauge lines to the Venturi tube or other measuring device. Upon closing the valve, the bleeding procedure stops, the equalising port closes, and the gauge is ready to read. The single valve simplifies operation, and makes the gauge foolproof. Since bleeding is effected towards the metering device it can be done at any time while, in the opposite direction, it may interfere with an experiment as it requires throttling of the Venturi or other measuring device.

A rack-and-pinion operated position gauge *F* mounted on the front of the aluminium plate is graduated in tenths and hundredths of a foot, and can be read by means of a vernier to 0·001 of a foot.



The arm on the travelling portion of this gauge contains two cross hairs, one on each side of the glass tube, for reading the mercury column. Parallax is prevented by lining up both cross hairs with the eye before reading the meniscus of the mercury column. A small 25-volt bulb on the arm of the position gauge adequately lights the portion of the gauge being read. As the ratio of the area of the mercury reservoir to that of the gage glass is small the level in the reservoir falls as the gage glass fills, thus each gauge should be calibrated. Usually discharge is calibrated directly against the scale on the rack-and-pinion slide gage. (Contribution of the Hydraulic Laboratory of the Bureau of Reclamation, Denver, Colorado, to *Houille Blanche*, Vol. 5, No. 4, 1950, p. 481, 2 pp., 1 f.).

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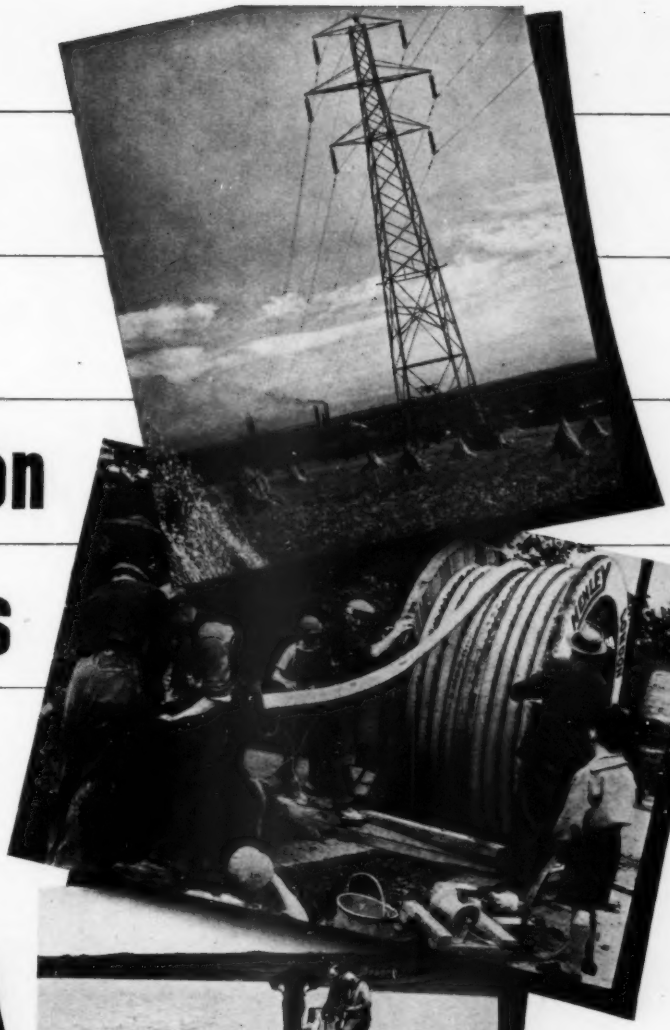

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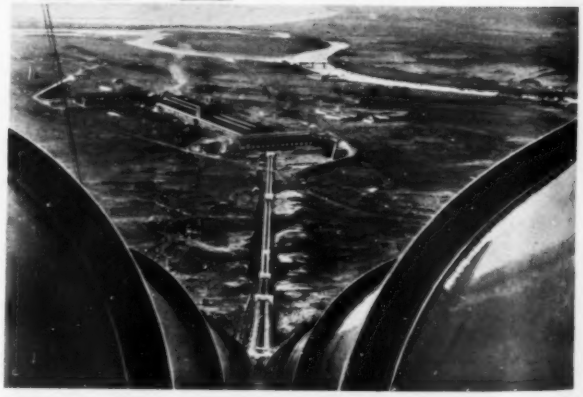

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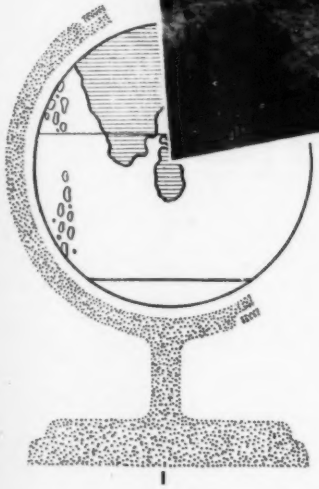

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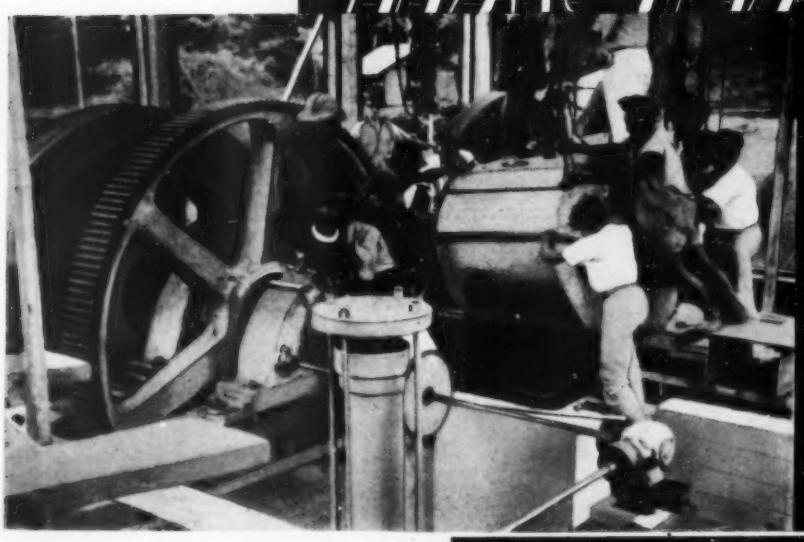

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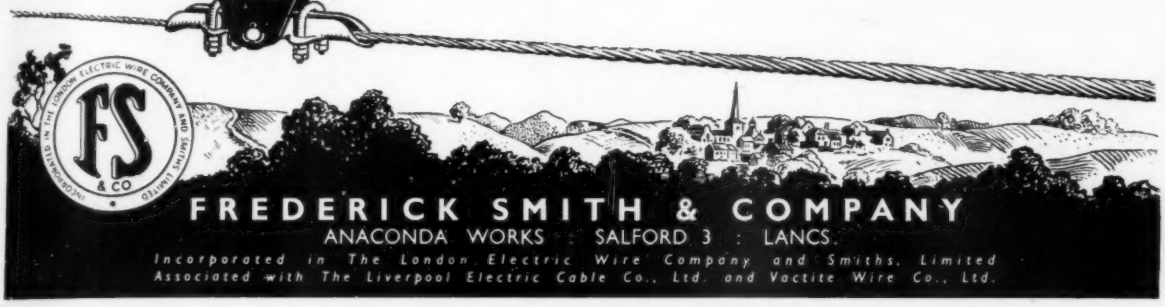

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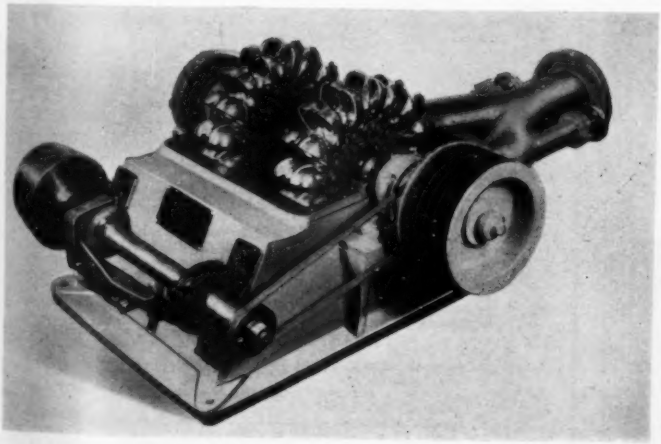

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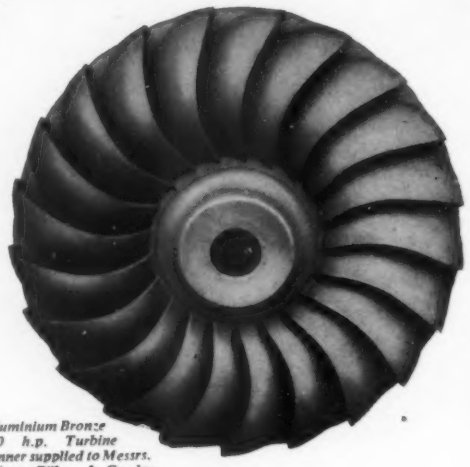

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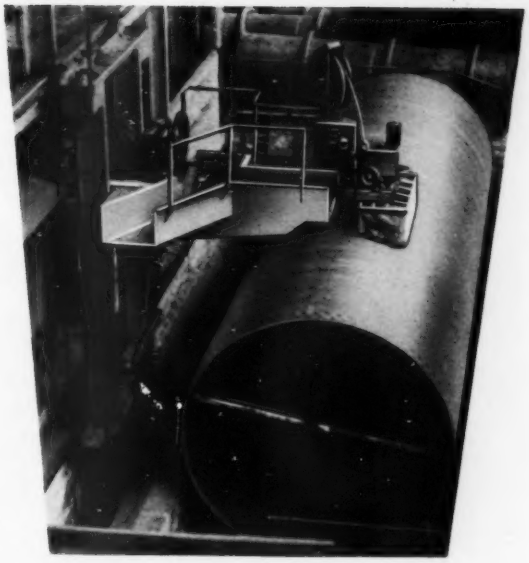

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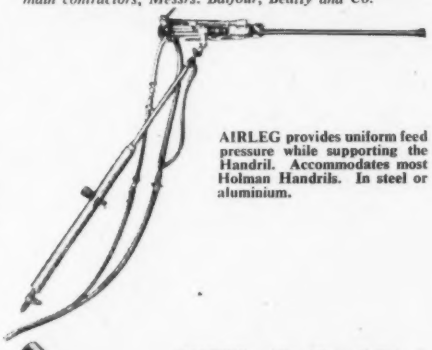

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